



Developing and resourcing academics to help students conduct and communicate undergraduate research on a large scale

Final report 2016

The University of Queensland (Lead Institution)

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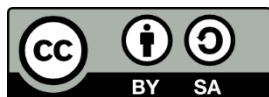
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List of acronyms used

ACSME	Australian Conference for Science and Mathematics Education
ALTC	Australian Teaching and Learning Council
ALURE	Authentic Large-Scale Undergraduate Research Experience
CASPiE	Center for Authentic Science Practice in Education
CoP	Community of Practice
CURE	Course-based Undergraduate Research Experience
HERDSA	Higher Education Research and Development Society of Australasia
LEAPS	Laboratory Experience for Acquiring Practical Skills
OLT	Office for Learning and Teaching
SoTL	Scholarship of Teaching and Learning
STEM	Science, Technology, Engineering, and Maths
TA	Teaching Associate/Assistant (Laboratory Tutor or Demonstrator)
UQ	The University of Queensland
URE	Undergraduate Research Experience
URNA	Undergraduate Research News Australia
URSSA	Undergraduate Research Student Self-Assessment Survey

Executive Summary

Context and Rationale

The practical laboratory is central to a science education (ACS, 2008) and, at its best, is an exciting place filled with challenge, discovery, and collaboration. Engaging students in real research is known to provide multiple benefits to those who participate. One model of achieving this is the Undergraduate Research Experience (URE). In science, the URE is widely adopted, however in the current context of expanding university accessibility, the capacity of this apprenticeship-style model to adequately serve large numbers of undergraduate students is being challenged. An American model, CURE, or Course-based URE, allows the research experience to be embedded in the regular teaching-laboratory curriculum (Auchincloss, Laursen, Branchaw *et al.*, 2014). For the past three years, the project team worked with tertiary educators to support the design and delivery of new large-scale Australian CUREs. We term the educational model 'ALURE' for 'Authentic, Large-scale URE'. In our experience, the implementation of ALURE in Australia occurs at the local level, and this is consistent with an Australia-wide audit showing that, at best, URE programs are supported throughout an individual university, but at worst they are championed by lone academics (Brew, 2010a; Jewell & Brew, 2010). This climate of low student access to undergraduate research, coupled with individual and often-unsupported uptake of the CURE/ALURE model in Australia informed the design and delivery of this project.

Project Aims

The project has focused on developing, embedding, and sustaining ALUREs in the Australian undergraduate science teaching context. We have engaged and worked with new and established academics who champion these models to determine best practices in implementing an ALURE. During this process we evaluated the outcomes for both the implementer and student participants. We aim to provide concrete guidance to academics and administrators about how we can sustainably (i) give more students these crucial experiences and (ii) provide the best learning environment for the student participants. The project team members are teaching-focused academic scientists; we aim to ask and answer these questions specifically for science ALUREs.

Project Approach

The dissemination strategy for the project is informed by the ALTC D-cubed project (Hinton, Gannaway, Berry *et al.*, 2011) and the essential climate for change already established by prior related projects (Brew, 2010b). The first phase of the project focussed on identifying potential adopters and building an online hub for an ALURE Community of Practice (CoP) (Wenger-Trayner and Wenger-Trayner, 2015 and references therein). Recruitment of new and interested academics through national networks and newsletters was low, and an online CoP was ineffective. Instead, the project team found that new adopters were best recruited through personal contact at conferences and workshops, while individual, in-person mentoring was effective in supporting novice implementers. CoP members met regularly at national-level conferences over the course of the project. These meetings were supplemented by site visits from the project team when implementers required support, or when the team was collecting data about an extant implementation.

The project team also developed several resources to support and inform members of the CoP and others interested in ALURE design and implementation. These are described in the Project Deliverables section; they were created using an action learning approach that incorporated both informal and structured feedback from CoP members

Once a new ALURE was designed and developed, multiple evaluation methods were used to investigate both the student and implementer experience. Validated instruments, reflections, and focus-group interviews informed our evaluation of the student experience. We evaluated the implementer experience through in-depth interviews and thematic analysis of the transcripts, along with informally collected and logged interaction with mentees and other academics.

Main Project Findings

Our work with new and established ALURE implementers showed that several key features were common to environments in which ALUREs became sustainably established. An individual academic championed the ALURE, developing and delivering the curriculum for students that they taught directly. This person was frequently supported by an environment that allowed (i) curriculum and assessment flexibility, (ii) workload negotiation, (iii) long-term, continuing “ownership” of a course or unit by the academic, (iv) some financial support for startup of the project, and (v) personal recognition of the effort involved. In most environments where a new ALURE is initiated and successfully delivered, new adopters in that institution have sought out the original champion as a mentor and the model is propagated into additional cohorts. In environments where one or more of these supporting factors (i) – (v) were lacking (or did not develop during the course of the project), champions found it difficult to establish an ALURE or to sustain it beyond one or two iterations.

Academic implementers reported significant satisfaction around their ALURE work, particularly with respect to their interactions with the students, and the recognition they obtained from their peers and institutions. Personal, just-in-time mentoring by mentors of the project team was identified as the primary support mechanism for academics who were setting up a new ALURE. In contrast, online mentoring through a CoP was ineffective.

Evaluation of ALURE from a student perspective shows that, when learning core laboratory process skills ALURE students neither ‘miss out’ on learning nor have an advantage over students in more traditional non-research undergraduate laboratory programs. ALURE students do report higher gains than traditional laboratory students in the development of science identity, critical thinking, and collaborative work skills; these learning outcomes have previously been reported in studies of apprenticeship-style URE participants.

Project Deliverables

The following deliverables were developed throughout the life of the project.

- **The project website** (<http://alure-project.net/>), which includes links to relevant publications, information about project activities, and team contact information.
- **An assessment framework for evaluating learning outcomes for ALURE students.**
- **Four “Implementer’s Checklists”** that provide a structured set of guidelines for novice implementers to use when developing an ALURE.
- **Exemplars of ALUREs**, which detail the ‘journey’ of developing, implementing, and maintaining an ALURE. They focus on the ‘implementer experience’ and are not descriptions or protocols of ready-made ALUREs.
- **A suite of student-articulated learning outcomes from ALURE participation.** Data was collected and analysed from ALUREs implementer at three year-levels, four institutions, and within multiple disciplines. This can be made available to interested implementers.
- **Project Artefacts.** Protocols, laboratory manuals, technical manuals, tutor manuals, task descriptions, assessment or marking rubrics, and exemplars of high quality student assessment work have been developed and catalogued throughout the project. They are available to interested implementers.

Project Impact and Sustainability

We have identified, documented, or implemented 21 different Australian large-scale UREs that fit the ALURE model. Eleven of these were developed in association with the authorship team. Six Australian tertiary institutions now run, and one plans to run, one or more ALUREs, with multiple disciplines represented. The scope of the CoP and the project engagement is shown in Appendix B. Five members of the CoP have received awards as recognition for their contribution to student education. One CoP member is planning an OLT Extension Grant. The project has provided five Honours and two Summer students with research projects.

We envision that the CoP and number of ALURE programs run in Australia will grow. We plan to continue supporting academics, but have already seen mentor-mentee relationships established between members of the network that suggest the CoP is approaching self-sustainability. Planned meetings at national conferences will also contribute to CoP maintenance; this has been one of the most effective means of engaging new implementers. Finally, the visibility of the ALURE model will be sustained as current implementers and project team members realise publications that are currently in progress.

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Chapter 1: Introduction

1.1 Context and Rationale

The practical laboratory is central to a science education (ACS, 2008), and it can be an exciting place filled with challenge, discovery, and collaboration for students who experience well-designed teaching programs. The Boyer commission report (Boyer, 1998) sparked a wave of innovations in research-led undergraduate teaching that has propagated across university curricula in Australia and internationally (Brew, 2013; Healey & Jenkins, 2009). These research-led projects are called undergraduate research experiences, or UREs.

The traditional apprenticeship-style URE in the sciences is a high-impact activity (Kuh, 2008) in which a student works with a professional research group for a defined period on a mentored project. Students who participate in this form of URE derive a number of benefits including meaningful engagement, increased academic success, and enhanced retention (Bauer & Bennett, 2003; Eagan, Hurtado, Chang *et al.*, 2013; Hunter, Laursen & Seymour, 2008; Hurtado, Cabrera, Lin *et al.*, 2009; Russell, Hancock & McCullough, 2007; Seymour, Hunter, Laursen *et al.*, 2004). In science, the apprenticeship-style URE is widely adopted, however this model cannot serve large numbers of undergraduate students. In contrast, the Course-based URE or CURE (Auchincloss, Laursen, Branchaw *et al.*, 2014), allows a research project to be embedded in the standard teaching-laboratory curriculum for hundreds of students in each semester. For the past three years, the project team has worked with Australian tertiary educators to support the design and delivery of new large-scale Australian CUREs. We term the educational model 'ALURE' for 'Authentic, Large-scale URE'.

Implementing a CURE/ALURE is a complex process, and factors that support and challenge large-scale CURE design and implementation have been summarised in recent studies. A US survey (Spell, Guinan, Miller *et al.*, 2014) reveals the biggest barrier that academics experience as they attempt to implement a large-scale CURE is lack of time. The 279 participants in this study also cited cost, resistance from colleagues, student numbers, and lack of institutional support as impediments. The project team believed that these same factors would be in play in the Australian tertiary environment. It has also been shown (Lopatto, Hauser, Jones *et al.*, 2014) that a collaborative reference group can support implementation and sustainability of large-scale CUREs in the American setting, however the American and the Australian tertiary sectors are very different. This project addressed ways in which academics could be supported to design, deliver, and sustain large-scale course-based UREs in Australia.

1.2 Project Aims

The project has focused on developing, embedding, and sustaining ALUREs in the Australian undergraduate science tertiary teaching context. We have engaged and worked with new and established academics who champion these models to determine best practices in implementing an ALURE and to develop their capacity to lead future ALURE activities. During this process we evaluated the outcomes from ALURE for both the implementer and student participants. The project consistently aimed to provide

concrete guidance to academics and administrators about how to sustainably (i) give more students these crucial experiences and (ii) provide the best learning environment for the student participants.

These activities are consistent with our original aim, which was to build a Community of Practice that (i) works together to develop leadership capacity in individual university academics who champion large-scale URE and student communication of research and (ii) informs senior administrators about the ‘coalface’ of large-scale URE implementation. We also aimed to collect, collate, and discuss information that can be used to give university administrators a clear and well-evidenced framework that they can use to verify the value of large-scale UREs and support these activities on a large scale in their institutions.

1.3 Project Outcomes

Outcome 1: Documentation of the range and diversity of Australian ALUREs and engagement with their academic champions.

Outcome 2: Investigation of the learning gains made by students who participate in ALUREs.

Outcome 3: An ALURE Community of Practice (CoP) that shares resources, mentors new ALURE adopters, and informs administrators.

Outcome 4: Professional development activities to help individual academics and university administrators implement and support ALURE.

Outcome 5: A set of ‘guidelines for change’ that can be used by university administrators to support ALURE and research-based learning generally in the Australian tertiary context.

1.4 Description of the Model: ALURE

This project used an extensive series of discussions with Australian tertiary science educators to develop a description of a feasible and sustainable model of Authentic Large-scale Undergraduate Research Experience (ALURE). The model, finalised in 2013, is described below. After these criteria were formulated a similar description of an authentic research experience in the US tertiary context was published (Spell, Guinan, Miller *et al.*, 2014).

- (i) An ALURE serves large numbers of undergraduate students (group of 50–500 or more);
- (ii) ALURE occurs in the undergraduate teaching spaces during regular class time;
- (iii) ALURE student work is mentored primarily by TAs (tutors) with academic guidance;
- (iv) the ALURE research project provides an opportunity for students to generate new knowledge which is valued by a real audience; and
- (v) the ALURE project work and assessment structure allows students to communicate their findings to that interested audience.

Introducing a large-scale research project for undergraduate students is not a trivial exercise, and an ALURE must be well resourced and carefully planned. This report describes our approach to engaging and supporting academics as they developed their

abilities to lead ALURE implementations, the major findings with respect to the aims outlined above, and the impact of, sustainability of, and lessons learnt from, this project.

Chapter 2: Project Approach

The dissemination strategy for this project is informed by the ALTC D-cubed project (Hinton, Gannaway, Berry *et al.*, 2011); the essential climate for change had already been established by prior related projects (Brew, 2010b). Here we describe how the project team approached and engaged established and new implementers on a local and national level, disseminated the ALURE model, supported the implementers, and finally evaluated the completed ALUREs.

2.1 Engaging ALURE Champions and Potential Adopters

Unsuccessful strategy

In the early stages of the project, there was a focus on publicising the aims and potential outcomes to implementers of new ALUREs. A major proposed outcome of the project was to build an ALURE CoP. In 2012 and early 2013, initial members of the CoP were identified and engaged, and an online wiki was developed to foster and encourage these connections. The project was advertised through multiple online and in-print avenues to learning networks, CoPs, and associations including SaMnet, VIBEnet, CUBEnet, the HERDSA membership, and Angela Brew's URNA community. Using these methods, the team aimed to identify and engage potential adopters and change agents within Australia's tertiary landscape. The project wiki was, however, infrequently used, and while the aforementioned methods of engagement and dissemination increased the project's visibility, they were ineffective in 'recruiting' new implementers.

Successful strategy

Instead, attendance and presentation at conferences, and personal interaction with interested academics proved to be the most effective way to build interest and find new implementers. The CoP established in the early stages of the project was maintained and expanded during the next phase of the project, where academics began designing, developing, and implementing their ALUREs. The workshop conducted at HERDSA in 2013, for example, garnered interest from new implementers from Deakin University and UNSW, who have since run two iterations of their ALUREs. In some cases implementers or change agents attended more than one conference presentation or workshop before they became part of the CoP. A comprehensive list of these in-person engagement and dissemination activities is presented in Table 2 (Chapter 5) and an in-depth discussion of the support provided to implementers appears in Chapter 3.

2.2 Developing and Resourcing Academic ALURE Implementers

In the first phase of the project, where new ALUREs were in development but for the most part not yet implemented, the Project Team (Rowland, Zimbardi, Lawrie, Wang, Myatt, and Worthy) instead implemented and evaluated our existing ALUREs. This allowed refinement

of evaluation procedures and increased our understanding of the essential characteristics of the ALURE model.

The project team (henceforth called ‘the team’) also interviewed existing ALURE champions about their programs, and used these discussions to develop ALURE exemplars that detailed the implementers’ challenges and successes (Chapter 3). To date, four exemplars have been created (Chapter 6). Together with the team’s ALURE implementations these exemplars formed the basis of the ALURE model.

The team then used this model to present a series of interactive workshops and talks at 15 venues in Australia and internationally (ALURE-only activities in Table 5.1, Chapter 5). The workshops were designed to recruit new implementers, inform potential implementers about ALURE, and gather data so we could develop best-practice guidelines for ALURE implementation. The team developed a ‘go-to’ resource to guide novice implementers during our discussions around starting an ALURE. The resource has subsequently evolved into the four separate *Implementer’s Checklists* (Appendix C).

The Checklists were developed in draft form using the team’s ALURE development process as a starting point; they were subsequently refined based on feedback from workshop participants. In particular the team engaged the workshop participants in discussion of: (i) how implementers felt they could feasibly give their students an authentic large-scale undergraduate research experience that fit the proposed model and (ii) what supporting and mitigating factors are associated with such an implementation.

One particularly useful methodology was to give potential implementers the opportunity to identify one of their ‘problem’ cohorts, then provide a ‘grand tour’ (Spradley, 1979) of the typical learning issues they faced with this group of students. Participants were also asked to define why this group of students were suitable candidates for ALURE implementation. This method elicited deep, but targeted, reflection from participants. It helped them focus on an area or cohort for which they could make a manageable change through consideration of why and how their effort would be valuable to their institution, their colleagues, and their students.



Figure 1: The Action Learning Process (adapted from (CLN, 2015).)

The team made audio recordings of the meetings and/or asked participants to write worksheet notes that were collected and collated (then returned to the participants). The contributions were used to refine both the working definition of an ALURE (Section 1.4) and the four final *Implementer’s Checklists*. Questions drawn from the *Checklist* drafts were used at all dissemination activities while full drafts of the *Checklists* were trialled at two workshops; APSTIL 2013 and ACSME 2014.

The dissemination activities drew on an Action Learning Approach (Revans, 1982) (Figure 1) to encourage discussion and change on the part of participants. Kramer (2007) (Kramer, 2007) states

that in order for Action Learning to effect change on a larger scale, individuals must first “unlearn” pre-existing ideas and “*change...their own mindsets – taken-for-granted values, assumptions, beliefs, and attitudes*”. This is precisely what is required when altering teaching practice to embed an ALURE in place of a traditional ‘cookbook’ practical. We recognise the risk associated with shifting teaching practice in ALURE implementation, and potential implementers must be allowed to approach the innovation through their own motivation, disciplinary skill set, and intent. Consequently the Team’s approach to these in-person dissemination activities was to present the ALURE model, then support participants as they discussed the complexity and challenge the model posed in their context. This approach addressed the question: *What kinds of support do novice academics need when implementing their ALURE?*

The team drew from Action Learning in several ways. During workshops and meetings, interested academics frequently raised concerns by asking ‘powerful questions’ about ALURE implementation (*‘How do I accommodate my large cohort?’*). Through ‘active listening’ to these concerns, the Team members shared their experience of implementing ALUREs, the challenges they encountered, and their strategies for success. Informal feedback collected through emails and discussions with mentee implementers, and during conference workshops, further informed the team’s understanding of the perceived barriers and opportunities in ALURE implementation. Feedback received was ‘reflected’ upon in Team and workshop discussions, and revisions to the Checklists were made accordingly (‘action’).

The *Implementer’s Checklists* are now a resource that encourages Action Learning in the user, allowing for ‘group and individual development’ when new ALUREs are being designed; they have prompts, examples, and structured reflective writing tasks that lead the user to actively address questions about their own ALURE. The four Checklists examine Design and Logistics, Support for Students, Evaluation, and Motivation and Value. The final Checklist helps implementers establish how they will develop leadership capacity by evidencing the value of their work and engaging stakeholders with the ALURE process.

2.3: Evaluating the Student and Implementer Experience in ALURE

A mixed-methods approach was used to formally evaluate each individual ALURE implementation, from both the student and implementer perspective (Figure 2). Ethical clearance was obtained for each institutional research site, with all participants providing informed consent to participate in the study. QSR Nvivo was used to identify and collate themes for all qualitative analysis, and all statistical analysis of quantitative scale data was performed in SPSS and MS Excel.

The student experience was primarily evaluated by collecting and analysing self-reported learning outcomes from student participants in ALURE. In some cases self-reported learning outcomes were also collected from non-ALURE students in the same classes as the ALURE students for comparison. The team developed a pre-post questionnaire, comprised of both validated instruments and items formulated by the team for this study. The combined instrument was trialled and validated in 2012-2013, followed by some revisions by the Team in 2014 to produce the final instrument (Table 1) used for all subsequent evaluations.

In 2014, an Honours student (supervised by Rowland) collected and analysed student survey data from seven ALURE implementations conducted in 2014. Data was also collected through semi-structured student focus group interviews (93 ALURE or non-ALURE students) as part of the Honours project. Qualitative student data from interviews and reflections was coded using inductive and deductive methods (using the learning gains framework from (Hunter, Laursen & Seymour, 2008)). Student outcomes were reported back to implementers, some of whom sought meetings with the Team to discuss these outcomes and their impact on future iterations.

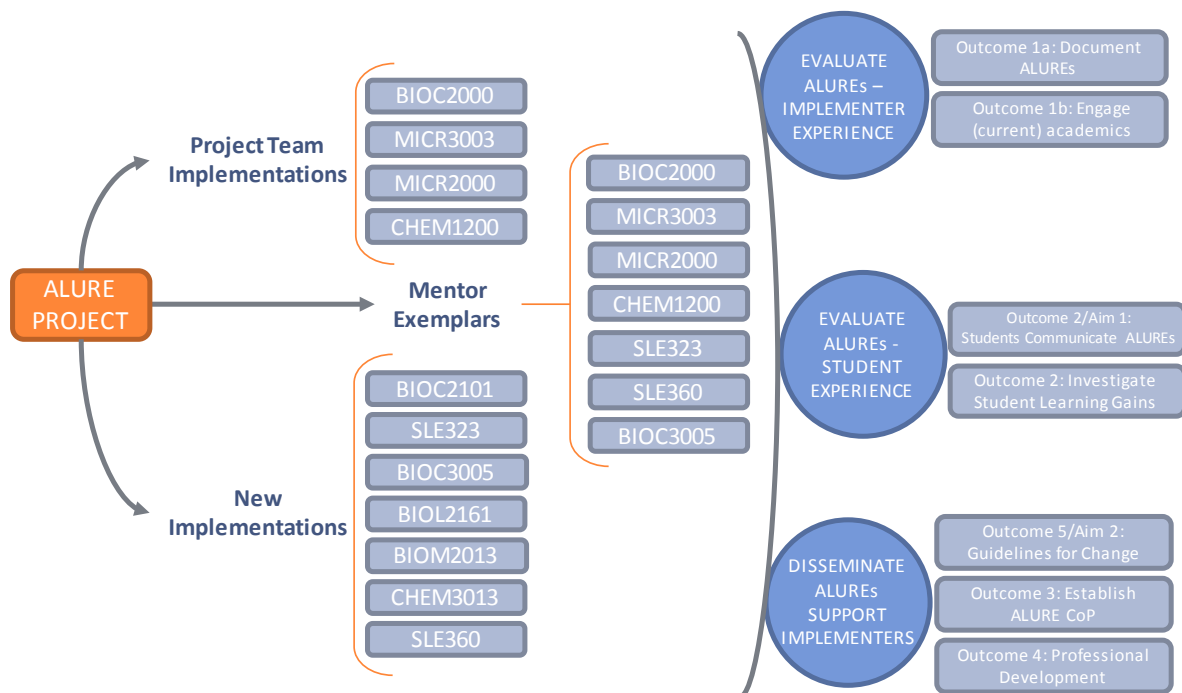


Figure 2: Project Approach and Scope. The courses listed represent sub-projects undertaken and evaluated during the project. In-depth accounts of ALURE design and implementation were collected from lead academics for the courses listed in 'Mentor Exemplars'. Four of these accounts have been presented as ALURE Exemplars (Appendix H). The blue circles to the right of the diagram are the main project activities; the aims or outcomes associated with each activity are shown on the right. The courses to the left are the subject of each activity. Appendix D presents an expansion of these core aims. Appendix E presents the Evaluation protocols and methods in detail.

The Implementer experience was initially evaluated by recording discussions with interested implementers during site visits and workshops (with consent). Much of this evaluation ran in parallel to the workshops and meetings described in Section 2.2. In late 2013 the team met with the Reference Group and External Evaluator who recommended expanding the scope of evaluation around the implementer experience to include implementers who have ceased running their ALURE and the wider support staff involved in each (such as TAs and preparatory staff). These recommendations informed the design of a second 2014 Honours project (supervised by Rowland). Twenty-one implementers, including course-coordinators, TAs, and laboratory preparation staff were subsequently interviewed at four Australian sites. Transcripts were deductively coded and additional emergent themes were identified.

Correlations between themes were explored to further characterise the supporting and mitigating factors associated with ALURE implementation. These additional data contributed to the development of the Implementer's Checklists.

Table 1: Core Components of the Evaluation Instrument. See Appendix E for a full version.

Survey Module or Question Set and Description
Undergraduate Research Student Self-Assessment (URSSA): A post-instrument with four core subscales. Students self-report gains in cognitive, affective, personal, and technical aspects of their experience. Modifications are described in Appendix E (URSSA, 2009).
Center for Authentic Science Practice in Education (CASPIE): Pre-post instrument consisting of multiple subscales, measuring student attitudes to learning in the laboratory and perception of science education (Scantlebury, Li & Woodruff, 2009).
CHEMX: Pre-post instrument to measure student attitudes to learning in the laboratory (Grove & Bretz, 2007).
Course Skills: Implementers use course learning objectives to define a list of commonly used and discipline-specific skills. Students report their confidence on list items before and after the ALURE using a 5-point Likert scale.
Roses, Thorns, Buds: This reflection framework is included in all post-surveys. Students use half a page of open text to describe the positives of the experience (rose), suggest improvements (thorn), and assess the impact of their experience on their future or attitudes to research (bud). These responses can be coded using deductive or inductive methods. Developed by the Project Leader, Susan Rowland.

Chapter 3: Project Findings

A rich and diverse suite of data has been collected as part of this project; the mixed-methods approach has enabled deep exploration the experience of ALURE implementation from three principal perspectives. These are the student experience, the implementer experience, and the support and development required in running an ALURE (Figure 1). A summary of each is included below. Callout 1 shows some student feedback for ALURE

3.1 The Student Experience in ALURE

The URSSA survey was used to examine students' self-reported learning gains in multiple aspects of their science identity. The full URSSA subscales are shown in Appendix E. Both traditional – or Laboratory Experience for Acquiring Practical Skills (LEAPS) - and ALURE students participated in the URSSA survey.

ALURE students report high levels of gain for the items in 'Thinking and Working like a Scientist' and 'Personal Gains Related to Research Work' (data not shown). These items include problem-solving and experimental design, and confidence in doing and collaborating

on research. The LEAPS responses for these subscales (data not shown) mirror this pattern. The results for the 'Behaviours and Attitudes' subscale (3a and 3b) show distinctly different trends between ALURE and LEAPS students. This subscale asks students to reflect on affective changes related to 'becoming a scientist'. ALURE students indicate overall, low-to-high level gains in these items. The trend in the LEAPS student data indicates more of the students feel they make low or no gains here. For the 'Gains in Skills' subscale, the results clearly indicate variation in gains for both practical streams (4a and 4b), however, there is an instrument effect here, as items in this subscale produce varied datasets according to how the skill is included in the ALURE structure.

Traditional laboratory programs are designed so students complete the series having learned core skills associated with the relevant discipline. To explore how ALUREs influenced student confidence in such skills, six of the 2014 evaluated courses included a list of core skills in the survey, to measure a pre-post student reported measure of confidence. For one course, LEAPS students also completed the pre-post self-assessment, with a total of 397 students represented in Figure 5.

'Technical skills' in this Figure are indicators of student ability in basic laboratory processes, while 'Analytical skills' measure their understanding and ability to problem-solve or use creativity. Appendix E contains a representative list of skills examined. For both LEAPS and ALURE students, confidence in both types of skills increased from the pre-survey to the post-survey across all courses. For each course, a Wilcoxon-Signed Rank test

Student View

I really enjoyed getting to have some experience doing research. The work was interesting and I felt that I was actually doing

It was great to have facilitated autonomy in a lab with a clear final goal which we worked throughout the whole

It has made me more independent and confident in the lab and has made me seriously consider a career in research.

Callout 1: The student view of ALURE

was used to compare the pre-post confidence score ($p < 0.05$). Significant differences in pre-post confidence were observed for the majority of skills included in the surveys for all but one ALURE.

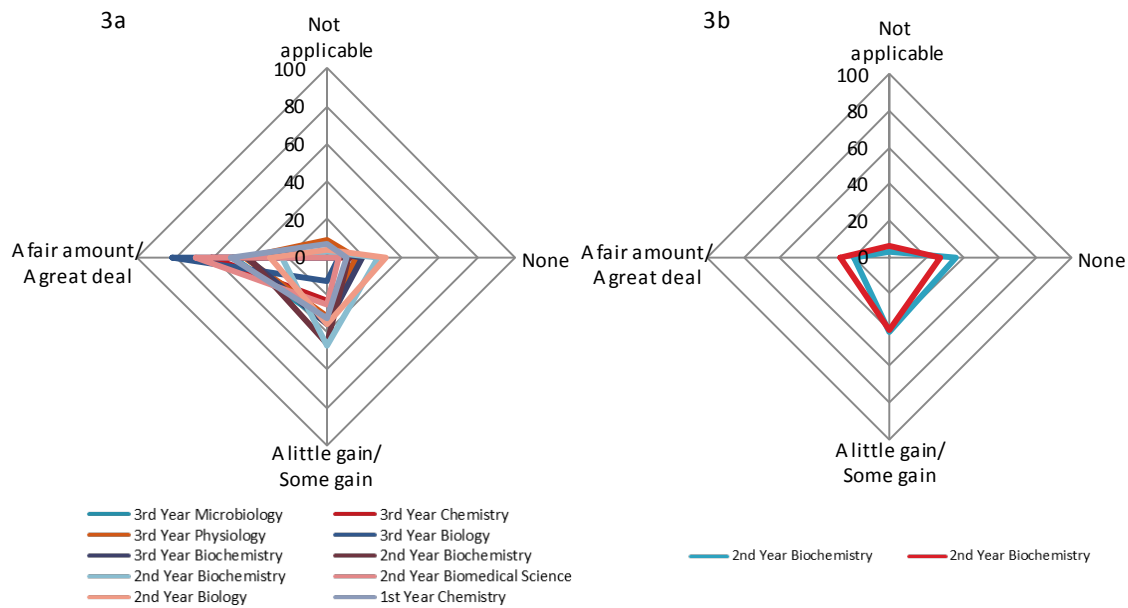


Figure 3: Aggregate Average Frequency of Responses to Items in URSSA Subscale 2 – ‘Behaviours and Attitudes’. Figure 3a: ALURE students, $n = 186$, ten individual implementations evaluated. Figure 3b: LEAPS students, $n = 442$, two different implementations evaluated. These students are LEAPS participants who chose to complete ‘traditional’ laboratory experiences in parallel with ALURE.

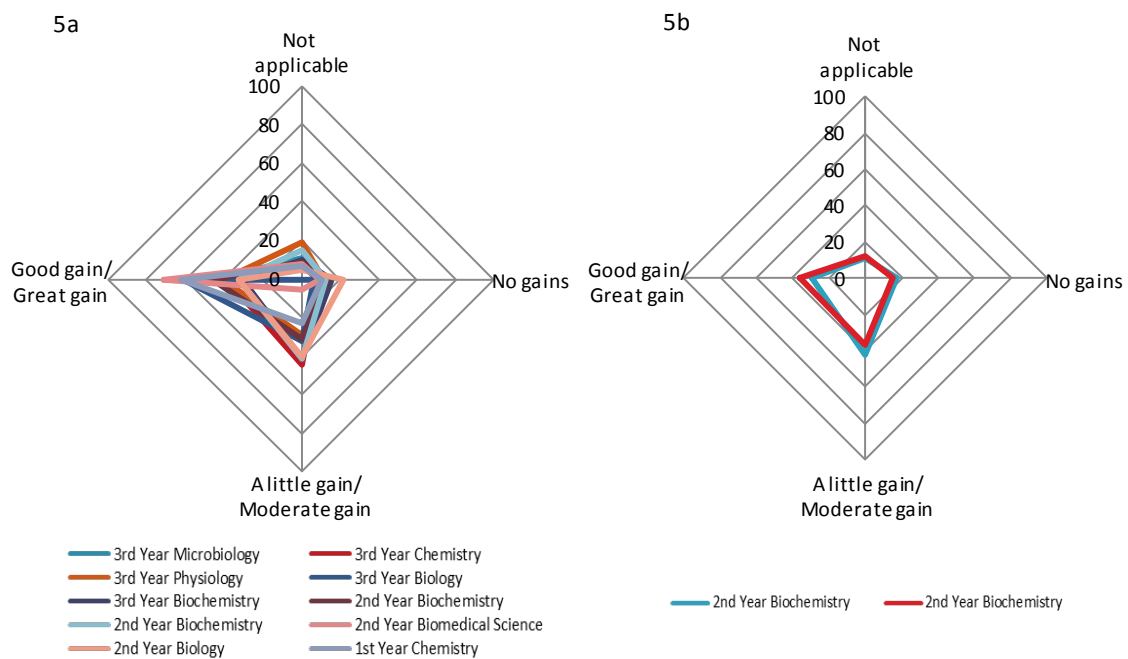


Figure 4: Aggregate Average Frequency of Responses to Items in URSSA Subscale 4 – ‘Gains in Skills’. Figure 4a: ALURE students, $n = 186$. Figure 4b: LEAPS students, $n = 442$.

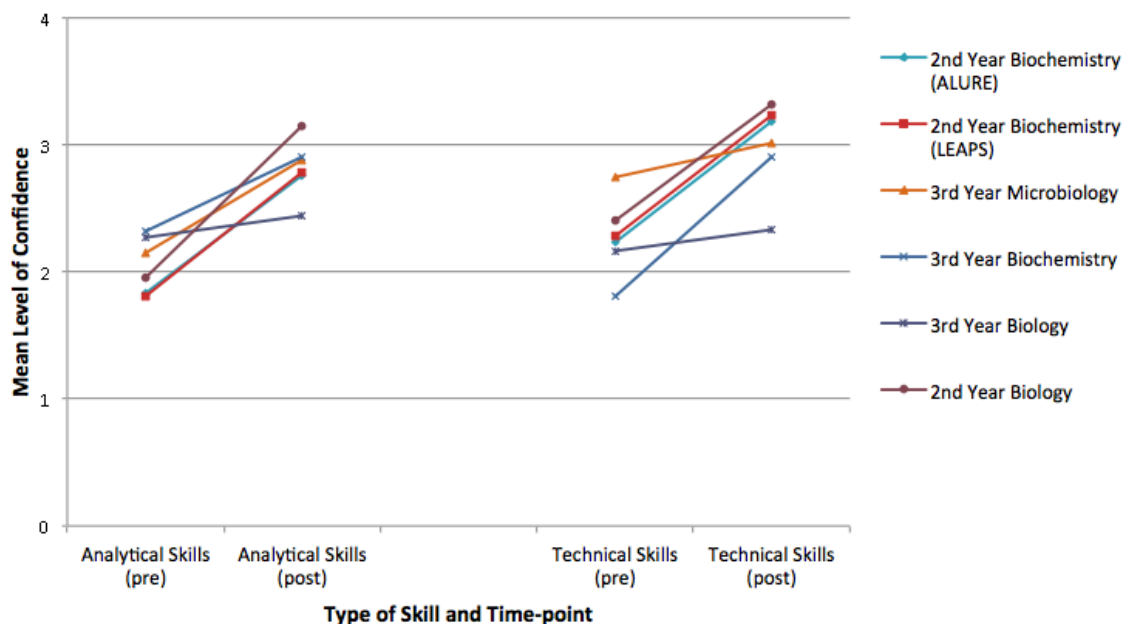


Figure 5: Mean Pre- and Post-survey Confidence Scores for Course Skills. Data points show the mean level of confidence measured on a 5-point Likert scale (0 = Do not know how to do – 4 = Highly confident) for all skills of either category (n = 397). n is smaller than the total number of students reached by the project, as not all students participated in evaluation.

The results show equity in skill development for LEAPS and ALURE students. This is an ideal outcome; ALUREs are not designed to provide advantage in learning course content. Rather, ALURE is an opportunity for students to engage in an authentic research environment and gain skills associated with this. Based on the URSSA data, on average ALURE students feel that they make more gains towards developing a science identity than LEAPS students. This suggests that ALURE provides students an enhanced opportunity to develop an identity as a scientist while maintaining their core skill attainment.

Finally, we briefly describe the qualitative feedback received from ALURE students. Using a *Roses, Thorns, Buds* reflection framework in the post-survey has resulted in a database of reflections from 186 ALURE students across 10 implementations (Figure 2). This framework was developed by author Rowland as an adaptation of the popular ‘Rose, Bud Thorn’ reflection tool used in American Summer camps. A *Rose* is a positive experience, a *Thorn* is something that can be improved, while a *Bud* is an emergent possibility or new idea. The *Roses* described by students are consistent across all courses. Students describe their experience as an ‘insight’ into real research, and report gaining a greater understanding of what research work is like. They appreciate the differences between a traditional laboratory series and an ALURE, citing factors such as the ‘hands-on’ practical work, increased responsibility and freedom, and the meaningful, real nature of the project. ALURE students describe increased ability to think critically, work with others, and confidence in doing research or performing laboratory work. The *Buds* of the student experience in ALURE vary widely; the experience may spark an interest in further research work, or confirm a previously decided path – whether in research or an alternate field. Negatives described in the *Thorns* are usually individualised to each course, and may include comments on the level of support, assessment items, and the time involved in the project.

3.2 The Implementer Experience in ALURE: Evaluation and Support

The second major point of investigation for this project was the implementer experience in ALURE (Figure 2 and Callout 2).

The initial project approach to supporting ALURE implementers was through the use of an online CoP wiki page. Here, implementers could access or upload resources and outputs, ask for input, or answer queries from fellow academics. Online analytics indicated that the primary use of the wiki was associated with the initial set-up activities and a sharp decrease in wiki access was observed starting in 2012 (once content was established). The team quickly discovered that academics were rarely using the wiki, and that the best method for engaging, developing, and supporting novice ALURE implementers was through in-person or technology-enabled (email, skype etc.) mentoring.

In-depth interviews with ALURE implementers and feedback from members of the CoP allowed the determination of some key factors that supported successful design and implementation of an ALURE.

3.2.1 Institutional Resources

Resource costs can be higher per ALURE student than for a traditional laboratory route, so institutional support of the activity is essential. Implementers reported they needed extra time and money to prepare the project materials and buy equipment and reagents; their institutions responded with financial support for equipment and/or support staff. Although the student/TA ratio in ALUREs is generally the same as the traditional laboratory experience, the ALURE is less predictable than a traditional laboratory. This means that all staff associated with the ALURE will likely spend more time troubleshooting the project on a regular basis. The ALURE also requires different assessment mechanisms than a more traditional laboratory, because student participants need the opportunity to demonstrate their writing and problem-solving skills. Marking this can be time-consuming and it requires advanced disciplinary skills from the assessor. Where an ALURE became sustainable these aspects of the innovation were acknowledged and respected by the host institutions. In the absence of in-principle and in-kind support from the educational unit, establishing and maintaining an ALURE is difficult.

3.2.2 Student Support

In most undergraduate laboratory programs, students conduct exercises in which known results are predetermined and almost guaranteed. Consequently they need support when they attempt a research project with its attendant confusions and uncertainties. Feedback from students indicated that they needed scaffolding in theoretical background material as well as laboratory, design, and analysis skills. This was particularly the case in ALUREs where the whole class participated. Implementers needed to manage student expectations around

Implementer View



I feel so proud to be a part of it, I mean I gave the idea a shove... but it's been so successful because it's a team...

I have a very understanding boss and I think that if I didn't have that I wouldn't have been able to do 10% of the things that I've done...

For these projects getting a large class size is actually very beneficial and that's the way we designed it...

Callout 2: The implementer view of ALURE

the amount of work and the level of student autonomy required. Although most students were enthusiastic about the ALURE, members of the cohorts did exhibit a range of attitudes - from concern that they would not be 'smart enough' to do ALURE through dismay that they did not get full freedom to design and conduct experiments at will.

ALURE student mentoring proved to be complex. In some ALUREs the academic implementer spent considerable time in the laboratory with students who clearly appreciated their presence. TAs were also key members of the mentorship team and while some managed to transition to the ALURE teaching model easily, others struggled to facilitate student project ownership. This often happened because they were too keen to alleviate the discomfort and confusion of students who were experiencing failure. Still, it was heartening to see a significant level of peer collaboration reported by the student participants, particularly in ALUREs that provided (or allowed) opportunities for student groups to reflect, evaluate their data, and make independent, informed choices about their next step. In-class discussions, tutorials, and online interactions all supported this design element.

3.2.3 Flexibility

Not everything progresses smoothly in an ALURE laboratory, and experimental flexibility is crucial. Some implementers offered additional non-compulsory teaching sessions or intensive experimental blocks so students could complete the project. Implementers assessed process rather than product to encourage students to think through and address problems, rather than moulding them to pursue a 'correct' result.

Crucially, the ALURE model itself proved flexible, and each implementer designed their own ALURE, adapting the model and the topic to their own contexts and their students' needs and interests. Example structures for ALUREs in the project are shown in Appendix F.

3.3 Lessons Learnt and Challenges Overcome

Several challenges arose in the initial stages of the project that appeared to 'impede' its progress, however these enabled the evolution of a better model. Two original proposed outcomes for the project have been particularly affected.

3.3.1 The Challenge of Undergraduate Research Communication

The original outcome for the project relating to student gains was "Investigation of the learning gains made by students who write up URE outcomes for publication and dissemination." This has been partially completed through the characterisation of communication methods in 21 ALUREs and the communication-related evaluation questions in surveys and interviews. Nonetheless, as the complexity in developing and engaging students in an ALURE became apparent some original evaluation questions were prioritised over those that addressed student communication. Implementers also routinely compromised on the communication modes they had planned and the audiences they used for two reasons. Firstly, the amount of work involved in setting up and maintaining an

ALURE meant that implementers ran out of time to create and support a novel communication activity as well. In addition, the available class time and the students' skill levels meant that most ALUREs did not produce results of a quality that could be shared beyond the student and research group. There were two notable exceptions: students from one ALURE will polish their work and report their findings to the local council, while another has generated microbiome data that can be published in a peer-reviewed journal.

Ultimately, a sacrifice was made for the good of the learning experience. Learning, after all, comes first and above publication or output; *“while the main objective of mentored research is to produce science”*, we should remember that *“the main objective of research in laboratory courses is to produce scientists”* (Spell, Guinan, Miller et al., 2014). Instead of pushing the implementers to include novel communication activities in their ALUREs the Team set up an annual conference, ComScLE: Communicating Science, Improving Practice, Evidencing Learning. This conference was held in 2013 and 2014 with a total of around 100 attendees. Members of the CoP attended, as did non-CoP academics. Attendees have reported changes in their communication teaching practice and an increase in their understanding of what constitutes 'Communication' in science.

3.3.2 Lessons in Building a CoP: New adopters need mentors and institutional support

As explained earlier, an online CoP was found to be an ineffective platform for establishing or supporting a nationwide network of ALURE practitioners. Although CoP members (and others) regularly visited the project website (alure-project.org) they did not engage with the wiki, probably because it did not serve their needs. Individualised, rapid, and specific mentoring of new academic implementers returned the most effective progress with the least implementer stress. Communication through email, Skype, and telephone was effective once the team had established a trusting relationship with the implementer through initial in-person meetings.

Support for new implementers from the host institution must be established – a personal interest in implementing an ALURE from a single academic is not enough to sustain the process of innovation. The involvement of an additional person with institutional influence is a key driver. This person is the *central change agent*, someone who can advocate for, support and assist the implementer. Once this person is in place, the implementer may begin developing an ALURE with more confidence.

Implementers consistently needed guidance in three key design areas of ALURE: (i) student supervision, (ii) the research question, and (iii) the audience for the students' results. Providing exemplars of ALUREs for new implementers gave them much-needed insight into the process of implementation, but they all opted to design their own, unique ALURE based on personal interest. This approach was highly favoured by the team as it built empowerment and ownership in academics. For research experiences in particular, academics who “participate in decisions about what they teach [...] can integrate their research and their teaching more easily than if they are just told what to do” (Colbeck, 1998). The team members primarily acted as sounding-boards and 'reality-checkers'. New implementers identified and nurtured through the project have taken on the mentor role

for another academic at their institution. These smaller, local CoPs contribute to the overall ALURE network. Using this triad of the change agent, examples of extant ALUREs, and personal support, the team has facilitated the development and implementation of seven new ALURE programs at three universities over two years.

Chapter 4: Project Sustainability

The D-cubed Guide (Hinton, Gannaway, Berry *et al.*, 2011) is a key reference and touchstone for the sustainability strategy of this project. The Guide describes multiple factors that influence the ability of a project innovation to be sustained beyond the life of the Grant; these are discussed in the context of our own project below. One factor not detailed here is 'publication'; instead, Appendix G gives a list of extant and in-progress publications.

- **Embedding:** There are multiple ALUREs embedded within the normal course activities at UQ; some have been running for over three years at the time of writing. All ALUREs developed or defined in this project are classed as 'sustainable'; they have either run for multiple years, or a second implementation in the near future is planned.
- **Upscaling:** The ALURE model was developed at UQ in 2011. Since 2012 the project has facilitated adoption of ALURE in seven new courses at three institutions nationwide. Although the model was originally developed for a second-year Biochemistry course, it is now implemented in multiple disciplines and year levels.
- **Deliverable Outcomes:** The deliverables from the project are outlined in Chapter 6. All resources mentioned in this report will be uploaded and accessible from the project website (alure-project.net/). The extensive trialling and development of the main resource, the *Implementer's Checklist*, should ensure that this deliverable is easily understood by any new adopter.
- **Continued Team Involvement:** The project team has secured two annual meetings for members of the CoP to come together. The first is associated with the HERDSA Conference; a symposium where implementers present their work and hold open discussions with new and established CoP members. The first symposium was held at HERDSA 2015, Melbourne (Table 2). A second forum, ComSCiE was initiated as part of this project and will continue to be held annually either by itself or as an adjunct meeting to another national conference (e.g., ACSME, AuPs, ComBio). Apart from this, the project team aims to maintain intermittent contact with established mentors, and further involvement as new adopters become interested in the model, much to the same degree as is outlined in this report. Jan West, implementer at Deakin, is being encouraged and supported to submit an extension grant on the project.
- **Nurturing Continued Commitment:** We have already observed the formation of new mentor-mentee relationships outside of the project team, between new implementers and novice academics within the same institution (Appendix B). The project team will continue to provide support to all implementers who are yet to become fully enculturated into ALURE practice, as well as encouraging further new collaborations outside the team.

Chapter 5: Project Dissemination and Impact

This section lists the formal dissemination activities conducted during and arising from the project. Publications, conference proceedings and abstracts are detailed in Appendix G. A discussion of the project's impact on local, national, and international STEM tertiary education is also included. Phone calls, emails, Skype calls, and informal visits used to mentor implementers and collect data are not included.

5.1 Project Dissemination Activities

Table 2: Dissemination Activities

Date	Event title, location (Presenter) description (number attending) ¹
July 12	ASM, Brisbane (Wang) Talk on embedding research in Microbiology education (50)
Oct 12	ISSOTL, Hamilton, Canada (Wang) Talk on SoTL in large-scale undergraduate research projects (3)
Nov 12	ASM Microbiology in Maleny Meeting , Maleny (Wang). Talk on Undergraduate Research in Microbiology to bridge clinical diagnostics and molecular techniques (80)
May 13	RMIT, Melbourne (Rowland, Worthy) Meeting to discuss potential for ALURE implementation and the evaluation of their extant program (7)
May 13	UoM, Melbourne (Rowland) Meeting to discuss the potential for ALURE implementation (2)
Jul 13	HERDSA, Auckland, New Zealand (Rowland, Wang, Lawrie) Workshop with three talks to provide information to potential ALURE implementers (15)
Jul 13	VIBENet, Melbourne (Rowland) Workshop to provide mentorship on OLT project applications using the project as an exemplar (70)
Jul 13	IUPS, Birmingham, UK (Zimbardi) Poster on ALURE Learning Outcomes
Aug 13	UQ Research Symposium, Brisbane (Wang). Talk on Embedding Undergraduate Research through Microbiology at a School Research Symposium (80).
Sep 13	ACSME, Canberra (Rowland, Lawrie) Workshop to provide information to potential ALURE implementers (20)
Sep 13	CUREnet, Chicago IL, USA (Lawrie, Rowland) Meeting with CUREnet to discuss methods for assessing learning gains of students in UREs (15)
Oct 13	Deakin Workshop, Melbourne (Rowland, Wang) Workshop to provide information to potential ALURE implementers (15)
Nov 13	UNSW Workshop, Sydney (Rowland, Worthy) Workshop to provide information to potential ALURE implementers (9)
Nov 13	ComSciE Meeting, Brisbane (Whole team) Meeting to focus on student learning in the context of their communication of science (55)
Nov 13	Reference Group Meeting, Brisbane (Whole team) Meeting to discuss the progress of the project (15)
Dec 13	Curtin Workshop, Perth (Rowland, Worthy) Workshop to provide information to potential ALURE implementers (7)
May 14	ASMCUE, Danvers MA, USA (Wang) Talk on Embedding Undergraduate

	Research throughout Microbiology majors (80)
Jun 14	APSITL, Bar Harbor, USA (Zimbardi) Workshop on Best practices for Undergraduate Research Experiences (21)
Jun 14	Deakin Workshop, Melbourne (Rowland, Worthy) Meeting for review of new implementation and discussions on development of second ALURE (7)
Jun/Jul 14	CUR Conference, Washington DC, USA (Zimbardi) Poster on Creating the Citizens of Tomorrow: Undergraduate Research for All (30)
Jul 14	HERDSA, Hong Kong (Myatt, Rowland) Talk on developing leadership through sharing successful models (20)
Sep 14	ACSME, Sydney (Whole team) Workshop on best practice for Undergraduate Research Experiences (15); Honours Student Poster presentations (Pedwell and Green) (150)
Oct 14	CUR Symposium, Quebec City, Canada (Rowland) Panel on leadership development (150)
Oct 14	ISSOTL, Quebec City, Canada (Rowland, Lawrie) Workshop on best practices for Undergraduate Research Experiences in Science (15)
Nov 14	ComSCiE Meeting, Brisbane (Pedwell, Green) Two Honours student posters on ALURE (35)
Nov 14	SCMB Research Students Symposium, Brisbane (Pedwell) Honours Student poster on ALURE (35)
Nov 14	AUPS Education Workshop, Brisbane (Rowland) Talk on developing science students' writing skills through UREs (65)
Nov 14	UQ Teaching and Learning Week, Brisbane (Whole team) Workshop on ALUREs to provide information to potential implementers (35)
Dec 14	UTS, Sydney (Rowland, Lawrie) Workshop on ALUREs to provide information to potential implementers (20)
Feb 15	CSU, Wagga Wagga (Rowland) Workshop on developing your role as a Teaching Focused academic (including a discussion of the project) (45)
Jun 15	UNSW, Sydney (Rowland) Meeting with ALURE implementation team to discuss data, paper production, and new ALURE development. Talk on Teaching Focused Academics and the role of the OLT. (40)
Jun 15	Gordon Conference, Lewiston ME, USA (Rowland) Poster on ALURE from the implementer perspective (40)
Jul 15	HERDSA, Melbourne (Rowland, Wang) Showcase Talks (x4) featuring talks from three implementers and project leader (50)
Nov 15	JCU, Townsville (Rowland) Workshops and Keynote presentation (100)

Notes: 1: Not all of the activities listed are exclusively dedicated to ALURE dissemination, however the ALURE project was mentioned and discussed at all of these events; Numbers of 20 or more for participants are frequently approximations

5.2 Project Impact

We have identified, documented, or implemented 21 different Australian large-scale UREs that fit the ALURE model. Eleven of these were developed in association with the authorship team while ten were developed independently. This project has had impact a local, national, and international level. The impacts span the student experience, institutional teaching and learning culture, and interdisciplinary linkages. The description of the impact of the project is based loosely on the areas of impact outlined in the IMPEL model (Hinton, 2014).

5.2.1 Local Impact

The ALURE model was first developed at the lead institution, The University of Queensland, in 2011. Members of the project team have since run multiple iterations of ALUREs in Biochemistry, Microbiology, Chemistry, and Physiology, across three year-levels. New ALUREs or adapted projects in these same broad disciplines have been implemented by a further five UQ Academics and their support teams. As part of this local CoP, a new implementer took on a mentorship role for a novice academic in 2014 (see Appendix B). Across all ALUREs at UQ, approximately 780 students are engaged in authentic research each year.

Members of the project team have received the following recognition for their contributions to teaching and learning practice:

- **Dr. Susan Rowland:** The University of Queensland *Award for Teaching Excellence (ATE) (2013)*; Australian Society for Biochemistry and Molecular Biology *Beckman Coulter Education Award (2014)*; and Australian Awards for University Teaching *ATE (2014)*
- **Dr. Gwen Lawrie:** Australian Awards for University Teaching *ATE (2013)*; Pearson Education RACI Centenary of Federation Chemistry Educator of the Year Award (2013)
- **Dr. Jack Wang:** 2014 The University of Queensland *ATE (2014)*.

This project also created Honours projects for five students and two Summer Scholars (Appendix D). In 2013, two Honours students worked on a related project on undergraduate research communication. Two Honours students working on the ALURE Project in 2014 had the opportunity to present their work at a poster presentation at ACSME; one of whom was awarded a student poster prize.

5.2.2 National Impact

Over the course of the project, the team has engaged with academics from multiple Australian tertiary institutions. At present there are three active institutions implementing or planning to implement nine ALUREs as a direct result of the project. The disciplines represented include Biochemistry, Physiology, Chemistry, Microbiology, Ecology, Genetics, and Biology. These ALUREs now sustainably serve over 1000 students each year as a direct result of the project. An additional invited workshop with three interested groups of implementers has been timetabled for late 2015 at a new implementation site.

Three implementers at Deakin University, Dr Jan West, Dr Steve Cheung, and Dr Lynda

O'Sullivan received the Vice Chancellor's Awards for Excellent Contributions: Staff 'Learning' Awards 2014 Deakin University Award for Teaching Excellence, and were invited to speak at a teaching retreat for their work in implementing STARS, a Physiology ALURE. Each of the new implementers have become advocates and local mentors for new implementers at their institutions; Jan West has presented her implementation at four national conferences and is planning an OLT Extension grant to introduce ALURE to the Engineering faculty at Deakin University. Dr Anneke Veenstra has been featured in a short film on her project. The team's interaction with additional identified course-based URE champions around Australia has led to a closer network of these academics and improved opportunities for collaboration and co-publication.

Most new implementers have as of July, 2015 completed two or three iterations of their ALURE. These academics feel confident in continuing to implement their ALUREs, and in some cases they mentor others; this speaks to the adaptability of the model in an Australian tertiary environment. It indicates strongly the potential for the continued growth and sustainability of this teaching and learning practice beyond the life of the project, as discussed in Chapter 3. The feedback from members of the Community of Practice also indicates a change in their teaching practice that contributes to the growth of the awareness of the value of teaching innovation research, and the recognition of SoTL in Australia.

5.2.3 International and Other Impacts

ALURE activities demonstrate novel ways of aligning with and achieving learning outcomes defined by both local and international curriculum guidelines. The OLT-funded Learning and Teaching Academic Standards Project for Science extensively describes 'Inquiry and Problem Solving', 'Communication', and 'Personal and Professional Responsibility' as Threshold Learning Outcomes 3, 4, and 5 (Jones, Yates & Kelder, 2011). The process of conducting and communicating and ALURE project develops all of these key outcomes for students. In a recent editorial comment to Team Member Wang, it was pointed out that ALURE also addresses "*the Vision and Change report and the American Society for Microbiology's undergraduate curriculum guidelines*" (Dr M. Allen, 2014--JMBE Editor, Hartwick College NY Biology Department Chair). The Vision and Change Report (Bauerle, DePass, Lynn *et al.*, 2011) specifically recommends integrating research into undergraduate classrooms as an action item for the American Biology curriculum, and ALURE clearly addresses this need.

The dissemination activities undertaken by the Project Team have further increased the visibility of Australian undergraduate research on an international scale. International impact is evidenced by invitations to Team members to present nine international workshops and conference presentations and participate in a small, high-level policy and planning meeting with CUREnet in Chicago. The resulting meeting report (Auchincloss, Laursen, Branchaw *et al.*, 2014) has been published, highly-cited, and re-published in the 2014 Highlights issue of CBE-LSE. Two international scholars have visited the Team during the life of the project to examine the ALURE model with the intention of implementing it in their own context.

5.3 Linkages to other OLT projects

The project has benefited from and used aspects from the following projects:

- **Enhancing Undergraduate Engagement Through Research and Enquiry** This ALTC Fellowship characterised and enhanced the presence of undergraduate research in Australian tertiary education. This provided an indication of the 'climate for change' needed to disseminate ALUREs (Jewell & Brew, 2010).
- **A Review of the Dissemination Strategies used by Projects Funded by the ALTC Grants Scheme – “The D-Cubed Guide”** The guide includes theory underlying dissemination, provides an approach to planning and undertaking dissemination, and lists possible activities (Hinton, Gannaway, Berry *et al.*, 2011).
- **Teaching Research: Evaluation and Assessment Strategies for Undergraduate Research Experiences** The authors used a long-term reflection exercise as a means of assessing student learning gains from UREs (Howitt, Wilson & Higgins, 2014).
- **An online writing centre for undergraduate students: a one stop shop (iWrite)** The outcome of this project, iWrite, was developed as an online resource to support undergraduate engineering students in their academic writing (Drury, 2013).
- **Identifying, building and sustaining leadership capacity for communities of practice in higher education** This project investigated how best to support academics in leading Communities of Practice, producing a set of resources for use by leaders in tertiary education. (McDonald, Star & Margetts, 2012)
- **Inquiry-oriented Learning in Science: Transforming Practice through Forging New Partnerships and Perspectives** This ALTC Fellowship evaluated, increased, and embedded inquiry-based learning in Australian tertiary science education (Kirkup, 2013).

Chapter 6: Project Deliverables

The following deliverables were developed throughout the life of the project. All are available to practitioners through the project website, which is also a resource in and of itself. These deliverables are designed to guide and inform practice when implementing ALUREs.

- **The project website** <http://alure-project.net/>. The website is a repository for the resources outlined below. The website also includes links to relevant publications, information about dissemination activities, and team member contact information.
- **An assessment template for measuring student learning outcomes related to participation in ALUREs (Appendix E)**: The project team has developed, and administered in multiple evaluations, pre- and post- assessment instruments using validated literature scales. This includes the modified URSSA instrument, evaluated to ensure validity is preserved in an ALURE context as a means for obtaining student self-report data in URE-specific learning outcomes.
- **The “Implementer’s Checklists” (Appendix C)**: These documents provide a structured set of guidelines for novice implementers to use when developing an ALURE. The design and content was informed through interviews with experienced implementers, those who are involved in supporting the implementers, and feedback from early trials and team members. It is available on the project website.
- **Exemplars of ALUREs (Appendix H)**: These exemplars detail the ‘journey’ of developing, implementing, and maintaining an ALURE. The four exemplars created (Figure 2) include perspectives from both novice and experienced implementers, whose ALUREs all have unique contexts and associated challenges. These exemplars focus on the ‘implementer experience’ and are not descriptions of ready-made ALUREs intended to be transplanted into a new context.
- **A collection of student-articulated learning outcomes from ALURE participation**. Data obtained and analysed from students in ALUREs of varying year level and discipline focus can be provided to sceptical or novice practitioners considering an ALURE implementation. These data can be shown to stakeholders and change agents, or used when evaluating an ALURE as a means of comparison or standards checking.
- **Project Artefacts**. The following documents have been developed or collected by the Project Team and members of the CoP: protocols, laboratory manuals, technical manuals, tutor manuals, task descriptions, assessment or marking rubrics, and exemplars of high quality student assessment work.

Chapter 7: Future Directions

7.1 Future Directions

The future directions for this project include undertaking the sustainability activities outlined in Chapter 3, as well as continuing the analysis of qualitative data collected throughout the project. The publications currently in progress and those planned in collaboration with new implementers are shown in Appendix G. It is important to help implementers write these papers, as publication from an ALURE may increase the host institution's motivation to continue providing support. A tangible reward in the form of a publication may also encourage other academics to adopt the model, increasing the capacity of the implementer to lead change at their institution. In progressing in the ways described, we have every reason to believe the ALURE model will continue to provide new learning experiences to thousands of Australian STEM students for multiple years to come.

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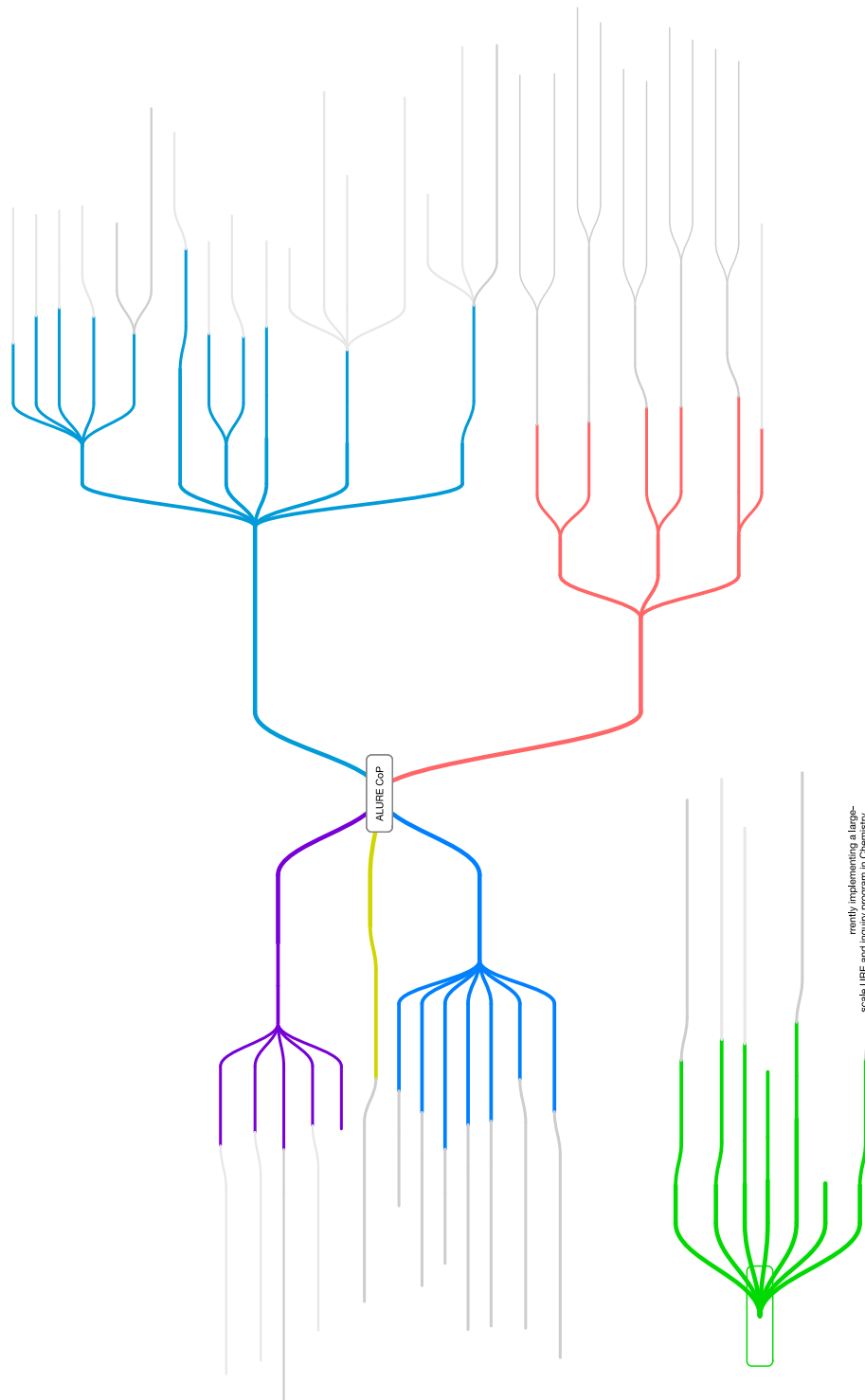
Appendix A: Certification by Deputy Vice-Chancellor

Certification by Deputy Vice-Chancellor (or equivalent)

I certify that all parts of the final report for this OLT grant provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name: Professor Joanne Wright, Deputy Vice-Chancellor (Academic) Date: 29/07/2015

Appendix B: The Project Community of Practice



Appendix C: Implementer's Checklists

This Appendix shows the first page from each Checklist. The full Checklists can be accessed at www.alure-project.net



ALURE Project

Implementer's Checklist - Design & Logistics



ALURE Project

Implementer's Checklist - Support for Students



ALURE Project

Implementer's Checklist - Motivation and Value

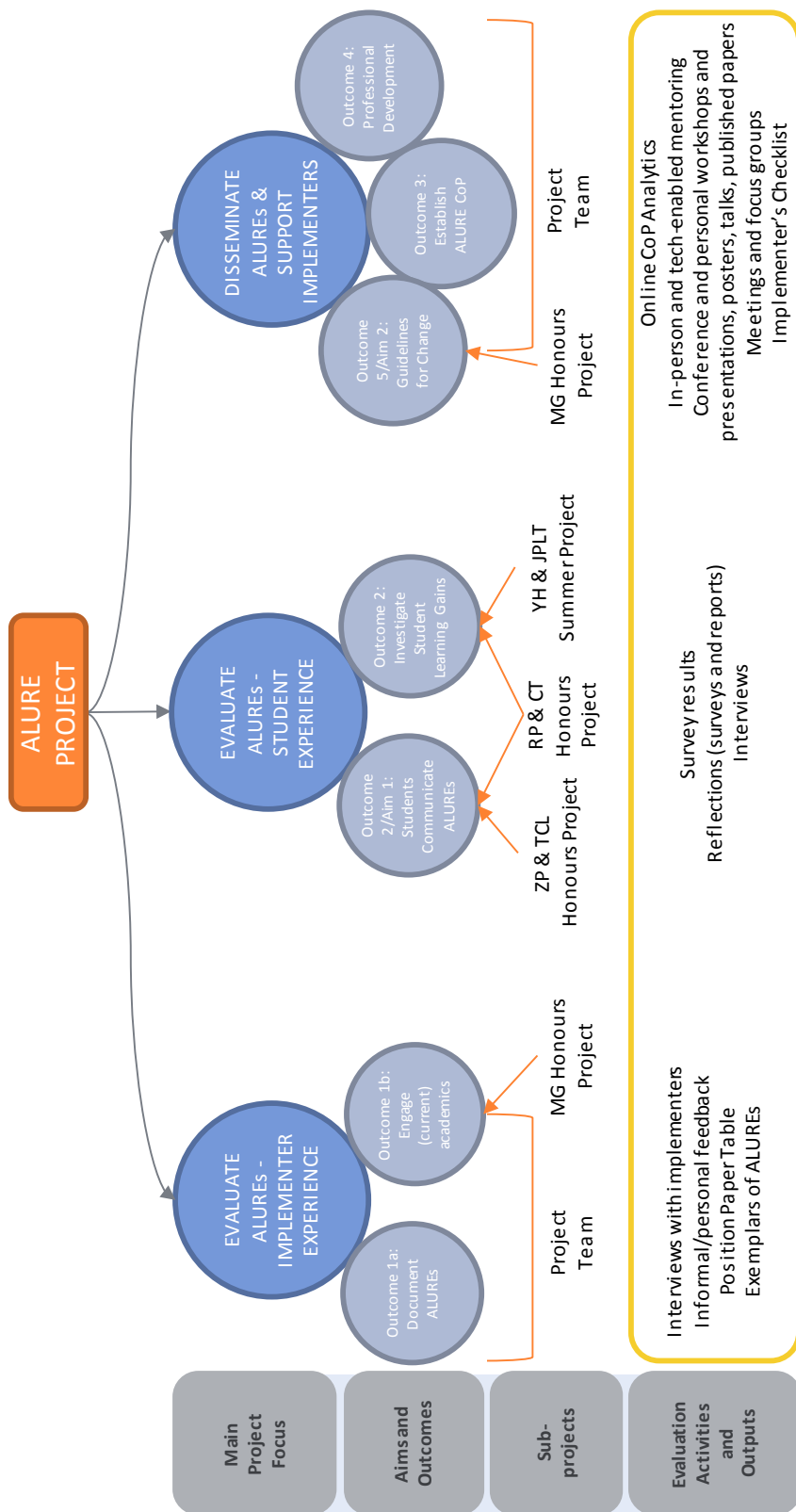


ALURE Project

Implementer's Checklist - Evaluation



Appendix D: Detailed Project Scope and Approach



Appendix E: Project Evaluation Framework

Table E.1: Evaluation questions, methods, and sources of data and evidence

Evaluation Questions	Evaluation Methods	Sources of Data/Evidence						
		Individual Interviews	Individual Interviews (Support)	Quantitative Pre/Post Surveys	Focus group Interviews	Reflections	Artefacts of each Implementation	Analysis of website
What are the features and the outcomes of a successful ALURE implementation?	<ul style="list-style-type: none"> • Application and evaluation of a design-based research methodology to match each implementation to intended learning outcomes. • Evidence of sustainability including dissemination. 							
What are the supporting and mitigating factors associated with ALURE implementation?	<ul style="list-style-type: none"> • Characterise key resources and support necessary for successful implementation. • Identify and remediate hurdles or barriers to successful implementation 							
What evidence can be extracted from this project to encourage others to adopt or adapt ALUREs?	<ul style="list-style-type: none"> • Identify the transferable elements of an ALURE 							
What are the learning gains students experience from ALUREs	<ul style="list-style-type: none"> • Evaluation of student learning gains through self-reporting instruments (URSSA, CASPiE, CHEMX) • Identification of emerging themes from qualitative data. • Development of benchmarking criteria for achievement of science inquiry TLOs. 							
What are the characteristics of an ALURE CoP? How can the CoP activity be sustained?	<ul style="list-style-type: none"> • Characterise activity on the project website. • Profile leadership activities exhibited by CoP members (mentorship activities, institutional recognition). 							
What are the most effective CoP activities to promote dissemination,	<ul style="list-style-type: none"> • Survey to examine changes in participant perceptions and behaviour around leading ALURE implementation. • Numbers of CoP members 							

<p>increase leadership capacity, and change the tertiary ALURE climate</p>	<p>mentoring novice & skeptical academics in implementing in ALUREs.</p> <ul style="list-style-type: none"> • Surveys to examine changes in participant practice after attending workshops and ComSciE meetings. 								
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Table E2: The URSSA Subscales

URSSA Subscales and Items	
Thinking and Working Like a Scientist	<ul style="list-style-type: none"> Analysing data for patterns Figuring out the next step in an experiment Problem-solving in general Formulating a research question that could be answered with data Identifying limitations of experimental research methods and designs Understanding the connections among scientific disciplines Understanding the relevance of research to my coursework Communicating the outcomes of an experiment Displaying experimental data in a scientific format Understanding the objective of an experiment
Personal Gains Related to Research Work	<ul style="list-style-type: none"> Confidence in my ability to contribute to science Comfort in discussing scientific concepts with others Comfort in working collaboratively with others Confidence in my ability to do well in future science courses Ability to work independently Developing patience with the slow pace of research Understanding what everyday research is like Taking greater care in conducting procedures in the lab or field
Behaviours and Attitudes	<ul style="list-style-type: none"> Engage in real-world science research Feel like a scientist Think creatively about the project Try out new ideas or procedures on your own Feel responsible for the project Work extra hours because you were excited about the research Interact with scientists from outside your school Feel part of a scientific community
Gains in Skills	<ul style="list-style-type: none"> Writing scientific reports or papers Making oral presentations Defending an argument when asked questions Explaining my project to people outside my field Preparing a scientific poster Keeping a detailed lab notebook Conducting observations in the lab or field Using statistics to analyse data Calibrating instruments needed for measurement Working with computers Understanding journal articles Conducting database or internet searches Managing my time

URSSA is a validated instrument, developed from research on traditional UREs, and intended for use in evaluating these programs. To measure any effects of the alternate context on URSSA (ALUREs) on

the internal reliability of these subscales, a Cronbach's alpha score was generated as part of each individual course analysis. The accepted threshold for internal reliability was set as $\alpha = 0.7$ (Pallant, 2007). The subscale average scores across all courses was above this level, with an average of $\alpha = 0.772$ (Subscale 2), up to an average of $\alpha = 0.918$ (Subscale 3). While individual course score 'acceptability' varied depending on how many participants were in the final sample, the team is confident that the URSSA is a viable instrument for use in ALURE evaluations.

Table E3: Example List of Experimental Skills included in Project Evaluation Surveys.

Technical Skills	
Serial dilutions	Weighing a solid
Calculating percentage yield from a purification	Making a simple graph to display experimental data using MS Excel
Determining the accuracy of a measurement	Doing calculations associated with dilutions
Creating and using a standard curve for macromolecules after gel electrophoresis	Performing basic statistical analysis using MS Excel
Interpreting the results of a protein gel	Running an enzyme assay
Preparing a sample for LC-MS	Reading a scale on a thermometer
Making a buffer	Pipetting 50 ul of a liquid
Preparing a reaction mixture for a restriction enzyme digest	Preparing and running an agarose gel for DNA analysis
Using semilog graph paper	Recording data in an appropriate format
Bacterial plating using streaking	Enzyme assays (and graphing the data)
Analytical Skills	
Collecting, sorting and identifying terrestrial invertebrates	Understanding what you are doing while you conduct experiments or a study
Drawing appropriate conclusions from results obtained	Using bioinformatics methods to examine protein structure and function
Integrating my results with other people's results	Troubleshooting when an experiment goes "wrong"
Understanding the different sample preparation strategies for LC-MS	Correlating the yield of a fermentation product with available starting nutrients
Using a plasmid map	Scoring and interpreting colony phenotype
Integrating data from different experiments to form a conclusion	Deciding if one experimental approach is better than another one
Interpreting the results of a DNA gel	Determining complementation of mutants
Reading and analyzing DNA sequences	Working effectively as part of a team
Designing PCR primers	Analysis of complex data sets
Doing enzyme kinetics calculations	Collating and analysing data
Planning experiments	The ability to write a testable hypothesis
Communicating data – oral presentation	Report writing
Isolating plasmids	Sourcing reference material using databases

Understanding genetic screening
procedures
Dealing with unexpected results

Using evidence to support a conclusion
Analysis of killing curves

Table E4: Student Experience Evaluation Interview Protocol

The student evaluation protocol was adapted from an exemplar, and questions developed using the guidelines in Hatch (2002). At the start of the interview, students were provided with an informed consent document and an introduction outlining the purpose of the interview. The questions listed are ALURE-specific but were altered for LEAPS students when required

(Introduction of participants) name and degree/major

Was this your first undergraduate research experience? Have you done research before?

What has your previous lab-based experience been like?

Have you done other ALUREs or participated in research in the past? Tell me what that was like.

What does research mean to you? (OR) What do you think of when someone describes “doing real research”?

What was your overall impression of the ALURE you participated in?

Why (if applicable) did you decide to do an ALURE?

How did you feel about doing an ALURE, instead of the kind of practicals offered in other courses?

How was the ALURE described to you? Did you feel prepared you for what you experienced?

How can this be improved?

Do you think ALURE was an authentic research experience? To what level?

What seemed like real research and what didn't?

Was this “real” enough for you? How can we make it better (more “real”)?

What sense of having ‘ownership’ of this project did you feel?

How does this project compare to other research experiences you have done?

Do you have suggestions for how we can increase your sense of ‘owning’ your projects?

How much did you feel a part of your lecturers and tutors research community?

How did you see yourself in relation to professional researchers?

How could the ALURE allow you to experience this side of research more?

How much did you get a sense of what being a professional research scientist would be like?

Did ALURE affect your opinion about what being a scientist is like? Why/not?

What was something that helped you to learn/have a good experience?

What was a negative aspect or something that hindered you in having a good research experience?

Could you tell me about your expectations going into the ALURE? How did these change throughout the experience?

Did you feel these expectations were adequately managed? How can this be improved?

Did you feel challenged by the tasks you were given? Why?/How?

Did you learn any new skills, or improve skills related to research and experimental design?

Compare the practicals you have done in other courses or research experiences to ALURE.

Could you describe the support you received throughout the ALURE?

From the implementers? From your peers? From the course material?

Was there a particular exercise or aspect of what you did that helped your learning or helped you have a better experience?

What did you take out of this experience in terms of thinking about your future and research?

How has your perception of yourself as a potential future scientist been affected because of the ALURE?

How has your idea of what research could be like changed?

How have your attitudes towards your future plans changed?

(Concluding question) could you please state one positive, one negative and one suggestion for improvement for ALURE?

Interviewer wrap-up.

Table E5: Implementer Experience Interview Protocol

[How much extra time] Is extra time required from implementers to run ALURE?

What strategies are suggested to help handle any extra workload?

Is ALURE preparation and delivering time considered in implementer's allocation of workload? What methods were used to negotiate this to be more realistic if it was not initially acceptable?

Are schools [or individual teaching programs or implementers] provided with the necessary funds and resources to effectively deliver ALURE?

Who needs to be [negotiated with] involved in negotiations with to get the appropriate resources to effectively implement ALURE?

What resources are most vital when it comes to implementing ALURE?

What challenges are associated with [found when] engaging students in ALURE?

What experience did implementers have and what strategies were used in managing student expectations of ALURE?

What support mechanisms were in place to assist students and do implementers believe that they were used satisfactorily?

How many students are required to make an ALURE feasible? (Minimum or Maximum)

What outcomes are the central administration and schools looking for when it comes to implementing a program like ALURE?

Did implementers have to manage these expectations? If so how?

How much support is given to Course Coordinators and other implementers and how is it delivered?

What support was useful?

What else could be done?

Is there resistance to change faced by potential implementers? If so how was it overcome?

Were there any governance issues with the institution as part of introducing new material to the curriculum? If so what?

Was the experience used as a basis for funds, awards or promotion?

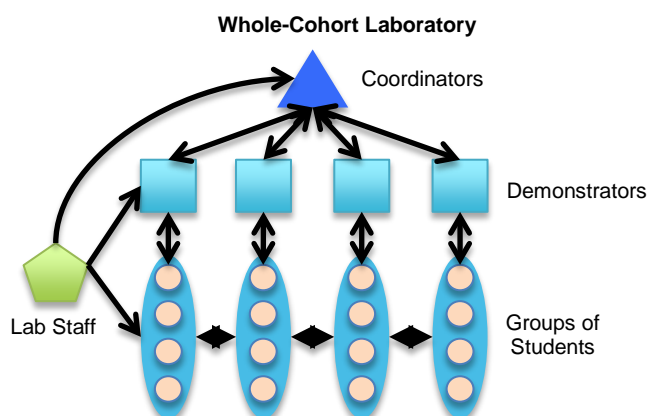
Was feedback received from management?

Was feedback received from students?

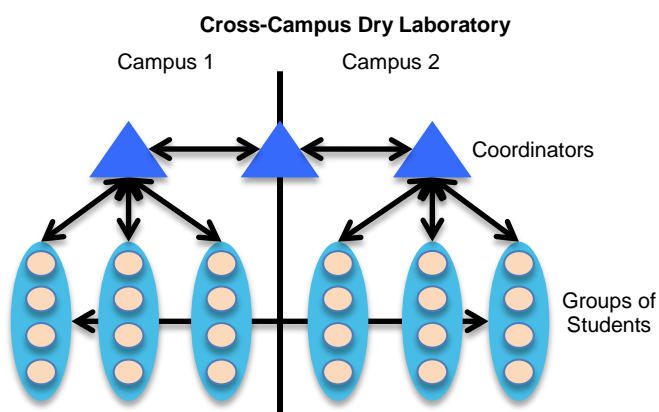
Did the implementation experience highlight new leadership opportunities?

Were there any outcomes that were not expected?

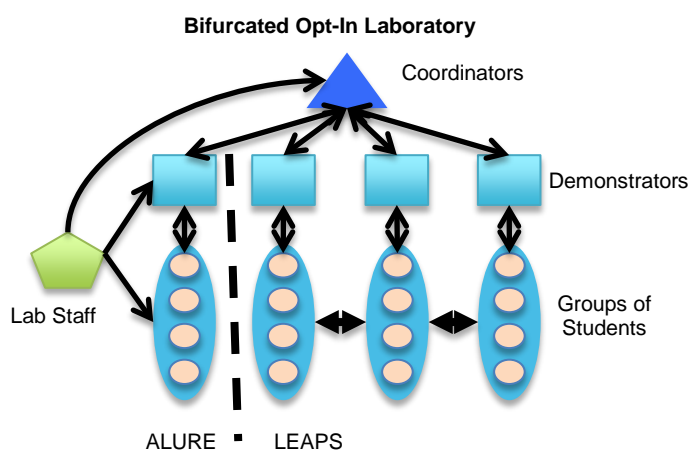
Appendix F: Types of ALURE Models



This model of ALURE completely replaces a traditional practical session and includes all students involved in a course. This model has been used in Molecular Microbiology subjects across two different institutions. TA to student ratios are between 1:10–1:16 with all students being able to support and share data between each group.



A new design of ALURE arose in 2014 at a new implementer institution, which had to deliver the same course to students across two separate campuses. The coordinators of this Advanced Topics in Biology subject decided to create a dry lab environment where students were the subjects, in order to make best use of resources and time. Three academics were the only staff required to deliver this experience to over 190 students. Students investigated the effects of chocolate intake and a number of other variables on their performance in online cognitive tests.



This model comes from the original ALURE design described in Rowland Lawrie, Behrendorff *et al.* (2012). It consists of two groups of self-selected students; ALURE and LEAPS. The ALURE students are generally the smaller group; their laboratory time is spent working on a real research project. In contrast, LEAPS students work in a more structured way towards a different experimental goal, but the same learning objectives. TA to student ratios operate at approximately 1:10–1:16. This model has been used for a number of years in various subjects at the University of Queensland as well as a new implementation in a Biochemistry course at the University of New South Wales.

Appendix G: Publications and Presentations Arising from the Project

G.1 Peer-reviewed Journal Articles

1) Rowland, S.L., Lawrie, G.A., Behrendorff, J.B.Y.H. and Gillam, E.M.J (2012). Is the undergraduate research experience (URE) always best?: The power of choice in a bifurcated practical stream for a large introductory biochemistry class. *Biochemistry and Molecular Biology Education* 40(1): 46-62.

2) Wang, J.T.H., Schembri, M.A., Ramakrishna, M. Sagulenko, E. and Fuerst, J.A. (2012). Immersing undergraduate students in the research experience. *Biochemistry and Molecular Biology Education* 40(1): 37-45.

3) Rowland, S., Green, M., Lawrie, G., Myatt, P., Pedwell, R., Wang, J., Worthy, P. and Zimbardi, K. (2014). The ALURE of Massified Undergraduate Research. *ASBMB Magazine* 45: 15-19.

4) Wang, J.T., Daly, J.N., Willner, D.L., Patil, J., Hall, R.A., Schembri, M. A., Tyson, G.W. and Hugenholtz, P. (2015). Do You Kiss Your Mother with That Mouth? An Authentic Large-Scale Undergraduate Research Experience in Mapping the Human Oral Microbiome. *Journal of Microbiology & Biology Education* 16(1): 50.

G.2 Conference Proceedings and Abstracts

1) Wang, J.T.H., Hall, R.A., Schembri, M.A. (2012). Constructively aligning assessment and feedback – a way forward for integrating SOTL theory and practice in large-scale undergraduate classrooms. *9th Annual International Society for the Scholarship of Teaching and Learning Conference (ISSOTL, Hamilton, Canada)*.

2) Rowland, S., Green, M., Lawrie, G., Myatt, P., Pedwell, R., Wang, J., Worthy, P. & Zimbardi, K. (2014). Best Practices for Undergraduate Research Experiences - Developing Authentic Large-Scale Undergraduate Research Experiences (ALUREs) in your Science Course. *The Australian Conferences on Science and Mathematics Education (ACSME), Sydney*

3) Myatt, P., Rowland, S., Lawrie, G., Wang, J., Zimbardi, K., Worthy, P. (2014). The ALURE of undergraduate research: developing leadership through sharing successful

models. *Higher Education Research and Development Society of Australasia (HERDSA), Hong Kong*

4) Wang, J., Hassan, H., Patil, J. & Pedwell, R. (2014). Supporting student engagement and transition through undergraduate research experiences in microbiology. *ACSME, Sydney*

5) Wang, J.T.H. (2014). Inquiry-orientated learning in microbiology: next generation DNA sequencing and the human microbiome. *Australian Society for Microbiology Educator's Conference (ASM EduCon), Melbourne*

6) Pedwell, R., Green, M., Lawrie, G., Myatt, P., Wang, J., Worthy, P., Zimbardi, K & Rowland, S. (2014) Impact of student approaches to ALURE: 'Swimming lessons' in the undergraduate laboratory. *ACSME, Sydney*

7) Green, M., Lawrie, G., Myatt, P., Pedwell, R., Wang, J., Worthy, P., Zimbardi, K., and Rowland, S. (2014) Investigating factors that support and challenge in implementing authentic research experiences for undergraduates. *ACSME, Sydney*

8) Wang, J.T.H (2014). Embedding Undergraduate Research throughout Microbiology Majors. *American Society for Microbiology Conference for Undergraduate Educators (ASMCUE), Danvers, MA*

9) West, J. M., Cheung, S, O'Sullivan, L (2014). A Large Scale Undergraduate Research Experience – Evidencing the GLO's. *2014 Deakin University Teaching and Learning Conference, Melbourne*

10) West, J. M., Cheung, S, O'Sullivan, L (2014). Reach for the STARS - A Large Scale Undergraduate Research Experience - communicating the findings. *ComSciE, Brisbane*

11) West, J. M., O'Sullivan, L. and Cheung, S. (2015). Dark Chocolate Improves Brain Performance in Undergraduate Students – Large scale undergraduate Research Experience. *STARS (Students, Transitions, Achievement, Retention and Success) Conference, Perth*

12) Kappler, U., Pedwell, R., Worthy, P. and Rowland, S. (2015). ALURE – using an enquiry driven undergraduate research experience to introduce students to systems biology. *HERDSA, Melbourne*

13) Wang, J.T.H., Daly, J., Patil, J., Hall, R., Schembri, M., Tyson, G. and Hugenholtz, P. (2015) ALURE: Undergraduate research into novel high-volume data sets within the human microbiome. *HERDSA, Melbourne*

14) West, J. and Veenstra, A. (2015) STARS and STRIPES: Flying the flag at Deakin in developing and implementing authentic large-scale research experiences (ALURES) in undergraduate units. *HERDSA, Melbourne*

15) Rowland, S. and Green, M. (2015) ALURE from the implementer perspective: academics and support staff navigate uncertainty and complexity as they design and implement authentic large-scale undergraduate research experiences. *HERDSA, Melbourne*

16) West, J (2015) Not just another written report: use of e-portfolio for the presentation of a research project. *D2L (Desire 2 Learn) Ignite Asia Pacific, Tasmania*

G.3 Publications in Progress

1) Pedwell, R., Undheim, E., King, G., Rowland, S. *A CURE by any other name: rebuilding a course-based undergraduate research experience to increase sustainability and maintain educational benefits* (in preparation for BAMBED)

2) Pedwell, R., Fraser, J.A., Wang, T.H., Rowland, S., Chatres, J., Clegg, J. *Budding Scientists: Delivering and Managing an Interdisciplinary, Authentic, Large-scale, Undergraduate Research Experience using Yeast Metabolism in Beer and Biofuel Production as the Context* (in preparation for CBE-LSE)

3) Rowland, S., Hung, Y., Lovie-Toon, J., Pedwell, R., and Worthy, P. *Student self-selection and self-authorship in a course-based undergraduate research experience and 'cookbook' practical series: The Roses, Thorns, and Buds of bifurcated laboratory programs* (in preparation for CBE-LSE)

4) Rowland, S., Green, M., and Pedwell, R. *Implementer perspectives on course-based undergraduate research experiences: An Investigation of Challenging and Supporting Factors, and Strategies for Success* (in preparation for BAMBED)

5) Rowland, S., Lawrie, G., Myatt, P., Pedwell, R., Wang, J., Worthy, P., Zimbardi, K. and other CoP members. *Designing, developing, and evaluating Authentic Large-Scale Undergraduate Research Experiences (ALUREs) in Science*. (HERDSA Guide pitch in preparation after discussion with editor of the HERDSA Guides)

6) West, J. and co-authors. *Stars and Stripes – a suite of undergraduate research experiences for research skills development* (in preparation)

7) Kornfeld, G., LeBard, R., and Lutze-Mann, L. *Publication on undergraduate research project* (in preparation)

8) Kappler, U. and co-authors. *An ALURE for systems biology* (in preparation)

9) Wang, J.T.H. and co-authors. *Using Undergraduate Research to develop transferrable skills for the modern workforce* Invited article in education issue of Microbiology Australia (published by CSIRO publishing) (in preparation)

10) Wang, J.T.H. and co-authors. *A hands-on practical examination to assess core laboratory skills in large undergraduate Microbiology courses* (in preparation for Journal of Microbiology and Biology Education in 2016)

Appendix H: Mentor Exemplars



Isolating Vaccine Antigens

Bacteriology

Dr Jack Wang, UQ

Key Concept

Learning the sequential nature of the cloning process and developing the skills to allow students to apply this experience to other scenarios

Summary

Using the molecular cloning process to isolate novel antigens that could confer protection against urinary tract infections.

Target Year Level

Advanced - 3rd level (offered in semester 1 of the final year of program)

Level of Research

Guided Inquiry

Pre-requisites

- Compulsory - Second year microbiology course
- Recommended - Second year biochemistry

Core Techniques

- Polymerase Chain Reaction primer design
- Quantify DNA fragments
- Complete a DNA ligation
- Express the cloned product into bacterial cells
- Check whether or not this has worked using PCR and DNA sequencing





The Extraordinary Power of Toothpicks and Logic Genetics

Dr Susan Howitt, ANU

Key Concept

How to use data to support a conclusion. This is done in the context of the *lac* operon but the focus is more on using data and particularly dealing with uncertainty because that comes out of the mutant screening.

Summary

Isolation and Characterization of *lac* Operon Mutants.

Target Year Level

2nd year

Pre-requisites

First year biology and chemistry.

Current Implementation Class Size

~200 students

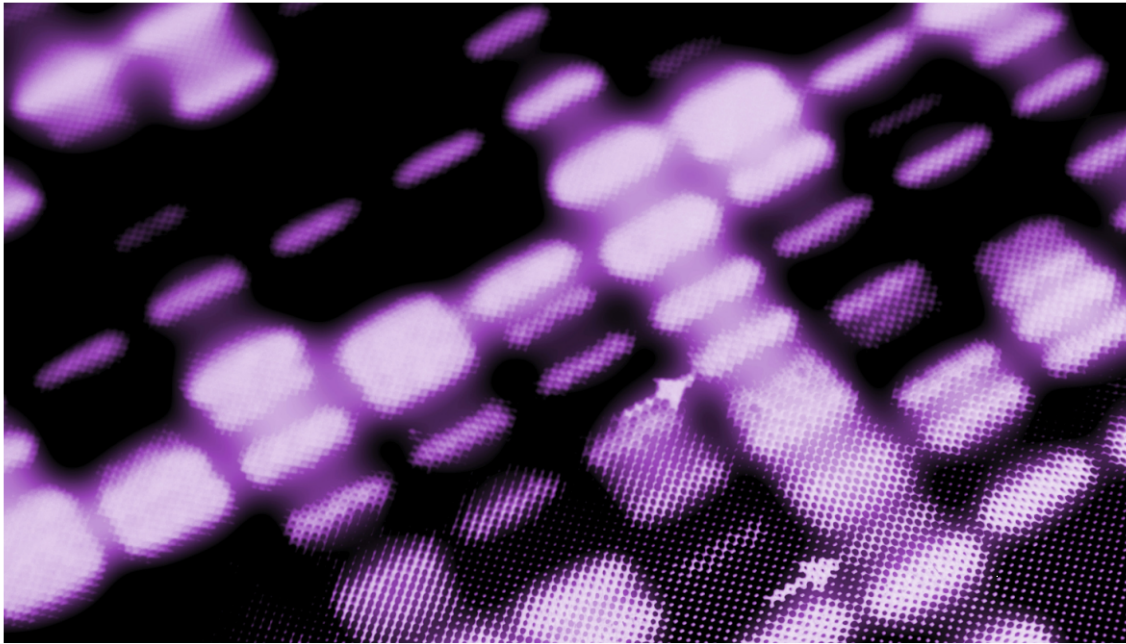
Level of Research

This lab does not fit within the label of open or guided inquiry. However, students do not engage with elements of experimental design and setting up experiments.

Comments on Level of Research

It does run cookbook style in that students have to follow set instructions. However, they are analyzing a genuine unknown. They isolate their own mutants. Then we pick two mutants for each 16 students (from the ones they've isolated) for analysis. The focus is on data analysis and coming to conclusions. This is the part that where students engage with real research.





Developing Bioinformatics Skills

Bioinformatics

A/Prof Liz Milward *University of Newcastle*
Dr Daniel Johnstone *University of Sydney*
Dr Jude Weidenhofer *University of Newcastle*
Dr Belinda Goldie *University of Newcastle*

Using Bioinformatics as an ALURE

Bioinformatics is a good vehicle for an ALURE because you can guarantee that everyone can find something compelling out of these large datasets. And it is something that is really their own and it works.

Even if the tests comes out negative, they can still get an original hypothesis that's their own.

Key Concept

Developing bioinformatics skills for extracting biologically meaningful results from large biomolecular datasets, and applying these skills to 'real' research microarray data.

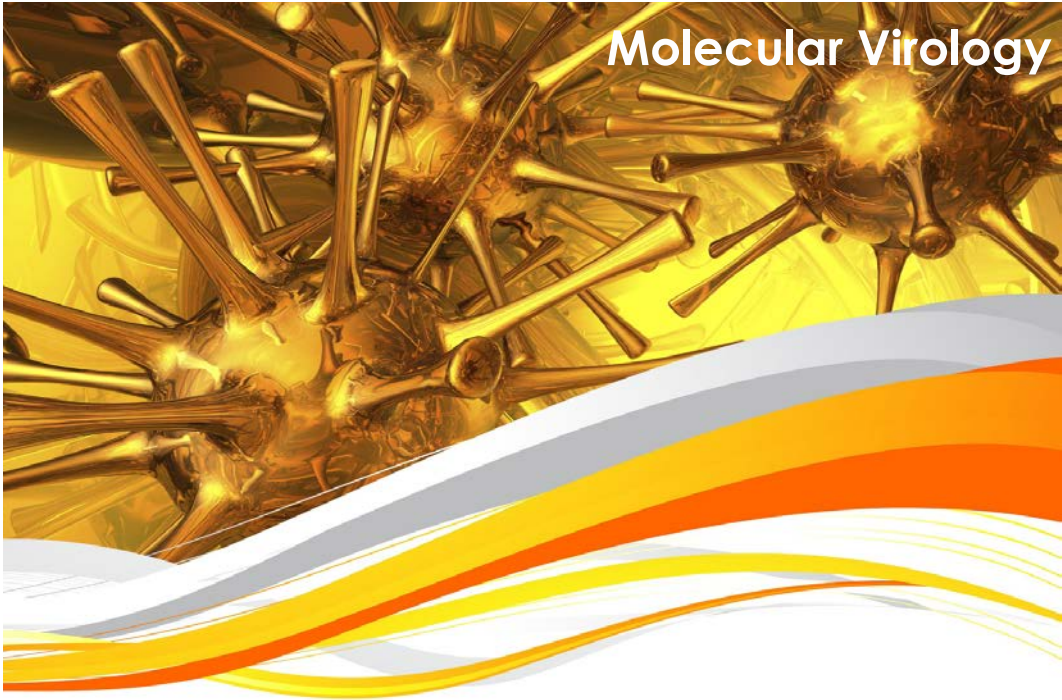
Summary

Guided but independent analysis of 'real' microarray data to identify molecular pathways and ontologies that are affected by an experimental manipulation or disease state and generate novel hypotheses on the inter-relationships between these molecular changes and the experimental manipulation or disease state.

Target Year Level

3rd year or advanced 2nd year





Molecular Virology

- pressed protein
- Enzyme assays

Appendix FINAL: External Evaluator Report