

Summative External Evaluation Report for ALURE: Promoting Authentic Large-Scale Undergraduate Research Experience

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1. Introduction

The project has sought to promote research-based learning in Australian universities by expanding the development and implementation of research-based courses in science known as ALUREs, or Authentic, Large-scale, Undergraduate Research Experiences.

The team based at the University of Queensland (UQ) had previously developed several ALURE courses in chemistry and the life sciences, based on a variety of types of research problems and using a variety of designs and structures adapted for first-, second- or third-year students.

Together these examples show a good range of possibilities for design of a research-based course and they have enabled the team to identify some general design principles and essential elements of ALUREs. Each course incorporates elements of research by opening up the investigative process to student independence, control and creativity at one or more distinct stages, while making it feasible to involve large numbers of students by keeping the investigation quite well-bounded at other stages. The “open” stage of investigation varies from course to course, thus offering the potential for designing ALUREs across a variety of scientific fields that offer different affordances and limitations for research-based laboratory work.

The goal of the funded project was to expand the availability of ALUREs to students at other Australian universities. The proposed strategies emphasized providing professional development to academics on how to implement ALUREs, cultivating leadership to promote ALUREs, gathering evidence about student outcomes, and informing administrators about this type of research-based learning. In large part these strategies remained central throughout the project, although specific tactics were adjusted over time.

1.1. Evolution of the Project Activities

Four main tactical changes are reflected in the evolving nature and objectives of the ALURE team’s work over the lifetime of the project. First, as the team worked, they found that academics did not readily adopt the courses that the original team had designed; rather, new adopters preferred to invent their own ALURE, tied to their own intellectual interests. The team’s theory of change thus shifted from developing and disseminating research-based courses to supporting academics to adopt the general ALURE concept and develop their own specific courses. The UQ courses and other early ALUREs became the case examples that could be shared with other institutions.

Second, the team found that face-to-face dissemination of the ALURE model was much more effective than was the online community of practice they had proposed. Thus the team invested

significant effort in expanding ALURE uptake and supporting new developers personally, by giving talks and workshops to interest other academics and help them conceptualize and map out their own ALUREs, developing support materials such as checklists for ALURE design, and providing one-on-one support for those who began to develop and implement an ALURE.

Due to these changes and the resulting net expansion of the range of content and audiences for ALUREs, the team shifted its research and evaluation approach somewhat. Publication-quality studies of student outcomes were seen as necessary to demonstrate the value of ALUREs, but these studies required quite substantial effort that could be daunting to adopters if they thought they had to invest this level of effort to assess their own work. Courses were not always ready for evaluation right away; some pilot work was needed. Thus an initial focus on gathering student data was adjusted to focus on work that would support other implementers in two ways. First, documentation of student outcomes in selected courses at UQ provided proof of concept to show others that the model works. The team has published some of these studies and other manuscripts are in the works. Those trying to build support for ALUREs on their own campus can point to such studies as evidence that student outcomes are beneficial. Second, these local studies offer models for new users, suggesting ways they might evaluate their own courses, whether through rigorous and comprehensive data-gathering intended as discipline-based education research, more modest studies framed as scholarship of teaching and learning, or through more easily implemented methods that provide formative data to improve the course.

Finally, studies of student outcomes were originally intended to focus on the role of student communication of their research results to external audiences, in venues such as undergraduate research journals. Getting students to this point in a single course proved more difficult than anticipated, and perhaps also less essential to securing the desired learning and psychosocial gains. While communication remains a topic of interest for the team, they shifted their approach from emphasizing student communication of ALURE outcomes to raising attention and exchanging best practices for teaching, learning and assessing communication in inquiry-based science courses more generally, through their Com ScIE conference.

1.2. Purpose and Scope of the External Evaluation

My prior work with the team has focused on formative evaluation. In October 2013 I visited the ALURE team in Brisbane, where I spent time with each member of the leadership team (alone and together), met with students, tutors and course coordinators from various UQ ALUREs, and participated in the reference group meeting and inaugural Com ScIE conference. At that time I provided formative evaluation advice in a follow-up conversation and a written report. I have remained in periodic contact since then, and the project has progressed substantially, so I do not repeat my prior findings and advice.

This summative evaluation seeks to provide the funder with an independent review of the ALURE project and its accomplishments. Secondly, I hope the team may benefit from some reflection of their work back to them. I focus on three main aspects of the project, asking the questions:

What has been learned about

- *Student outcomes of ALUREs and how to achieve them?*
While the project does not focus on students, they are the secondary and ultimate target of the project, as all ALUREs are intended to provide experiences that enhance student learning and psychosocial outcomes. Information on student outcomes thus serves as evidence that the ALURE model is effective and that it is being shared and taken up with appropriate fidelity.
- *The processes of developing and implementing ALUREs and supporting new adopters?*
New users are the main stakeholder group for this project, and it is important to understand what has been learned about how to help them develop and implement ALUREs on their own campuses and what assists them or stands in their way.
- *Supports and barriers that affect the longer-term sustainability of ALUREs?*
Getting an ALURE started offers certain challenges, and keeping it going offers both ongoing and new challenges. Although the duration of some of the current ALUREs is not yet very long, some insights are available on factors that influence sustainability.

Sources of information for this report include

- Skype interviews with the five core team members
- Online questionnaire data from a subset of ALURE adopters. I used this term to distinguish new users from the original ALURE developers, recognizing that they are adopting the ALURE model and not necessarily specific courses or curricula
- Review of documents, including
 - the team's original proposal, their website, and their final report to OLT
 - results of scholarly analyses, including published articles (Rowland et al., 2014; Wang et al., 2015), conference presentations (Green et al., 2014; Pedwell et al., 2014), a student thesis (Pedwell, 2014), and manuscripts in preparation (Pedwell et al., 2015; Rowland et al., 2015)
 - materials prepared for dissemination to practitioners, including four implementer checklists plus a set of notes that describes their intent (Myatt et al., 2015) and four "ALURE kits" or exemplars of particular ALUREs.

2. ALURE Adopters: View from the Second Wave

Because the team has focused its efforts on helping other academics develop and implement ALUREs in their own settings, these academics are the main stakeholder group for the ALURE project. Thus I gathered some independent data from a sample of these adopters, who represent the second wave of ALURE courses beyond the original UQ team. Their comments provide an independent perspective on project success and offer validation for claims made by the ALURE

team about how they worked with adopters and the kinds of supports adopters need, which are discussed in Section 3.

2.1. Evaluation Methods

A short online questionnaire was sent to seven ALURE adopters in August 2015. Items probing the respondent's role and scope of ALURE implementation at their institution were used to establish some context for their responses. Two open-ended items asked for respondents' observations about student outcomes, both positive and limited or negative outcomes. Two other open-ended items asked about resources or supports, and challenges or barriers, in implementing ALURE. One item asked the respondents to rate the prospects for sustaining ALUREs in their setting, another asked for "lessons learned" that they wished to pass on to other potential adopters; and a final item invited "any other" comment on their participation in the project.

Six adopters representing four universities responded to the questionnaire. Most described themselves as developers and instructors/coordinators of ALUREs; some also identified specific administrative roles. As a group, they knew of 14 distinct ALUREs taught in 9 academic units. The short open-ended answers were thematically coded for content using Excel, using emergent coding that was informed by the evaluator's knowledge of the literature on apprentice-model and course-based undergraduate research and of institutional change in education more broadly.

2.2. Student Outcomes of ALUREs

Adopters described several kinds of positive student outcomes from ALUREs, identifying gains in 19 comments. Some linked these to particular aspects of the ALURE that they felt led to or explained the outcome. The gains they noted fell into five main categories:

- Affective outcomes, including feelings of ownership of the project, a sense of achievement, enjoyment, interest, engagement and growth in confidence (9 mentions). One adopter noted, "Students took responsibility for their research and gained confidence over the course of their project." Another highlighted "watching the students' attitude change as they worked through the project—many believed they couldn't do it at the beginning—and their sense of achievement at the end." Some noted features of ALUREs that fostered greater student engagement: the extended project, meaningful class discussions, and authentic assessments.
- Application and development of scientific skills (4 mentions). Adopters called out both students' chance to apply previously learned skills in a research setting and to develop new (often transferable) skills, such as collaboration, time management, handling large data sets, and developing testable hypotheses.
- Deeper understanding of the practice and nature of research (3 mentions). One adopter highlighted students' gains in understanding both the practice of research (e.g, collaboration, literature searches, experimental design and planning, choice of appropriate tools) and the nature of research, that "not every experiment gives the result that you might expect; not every experiment works."

- Deeper understanding of science content (2 mentions). One adopter noted that students felt they could better integrate theory with practical work, and understood scientific ideas more deeply by working on a long project instead of short labs that were not linked together.
- Useful career connections (1 mention). One adopter noted that students “approach [me] to discuss their experimental design; as a result, I have far more contact with ALURE students than others. These students subsequently approach me more readily about items in the future, such as seeking references, or advice on how to enter the university's research degrees.”

The student gains observed by ALURE adopters align well with prior literature about student gains from research experiences and with those reported for first-wave ALUREs, suggesting that student gains are similar in the second-wave implementations and therefore that key features of ALUREs that account for student gains are preserved. Some student gains likely occur in most ALUREs (e.g., the commonly observed affective gains) while other gains (e.g., in forming hypotheses, handling large data sets) will depend in detail on the course design, especially what part of the ALURE course is open-ended and requires student decision-making.

Separately, adopters made seven comments on their observations of “limited or negative” outcomes for students, including:

- Issues with student teamwork (2 mentions), most commonly team members disgruntled with teammates who did not cooperate or share the work. Teamwork was reported as a minor, not widespread problem.
- Lack of coverage of certain content (2 mentions). One respondent noted, “The non-ALURE labs are designed to reinforce a lecture concept each week. ALURE labs do not cover as many lecture concepts in comparison, i.e. provide less revision of core course content.” However, another pointed out that, while non-ALURE students had exposure to additional concepts, this did not guarantee they had learned them well.
- Workload (1 mention): Workload became an issue if students did not keep up; it was harder for a student who had gotten behind to get caught up on a longer, cumulative project than to regroup and get a fresh start on separate smaller assignments.
- Student resistance (1 mention): “Some students... struggle with the idea of answering a question, as opposed to following procedures to get to a pre-determined outcome.”
- Students’ initial anxiety (1 mention): “Initially they found the project daunting and were wondering how they were going to be able to succeed. We had good resources that took them through the process. Student support through the process is essential.”

Again, these reduced or missing outcomes (in comparison with traditional laboratory work) are broadly consistent with the literature. Adopters indicated they were minor in number and in magnitude compared to the positive outcomes. As the last quotation notes, some of these issues can be mitigated or minimized by good scaffolding and structuring of the project and coaching of students through initial resistance to a more sophisticated understanding of how science works. I

contrast, breadth of content coverage is seen as a tradeoff against the depth of learning that is possible within the extended, applied setting of an ALURE.

While these observations are not equivalent to data directly from students, past qualitative studies have noted good alignment between student gains observed by academics and those reported by their students. These spontaneously offered comments describe outcomes that are plausible and consistent with those reported from other research-based courses.

2.3. Implementing and Sustaining ALUREs

Respondents noted 17 “resources or supports” that were important in implementing ALUREs, and 8 “challenges or barriers” faced in implementation. Due to similarity of the issues raised—a needed resource can become a barrier if it is absent—I combined these responses for analysis. The issues for planning and sustaining an ALURE included:

- Funding (9 mentions) Financial support was needed to purchase special materials and equipment, and to pay people, such as peer tutors and staff to supervise the course.
- Collegial support and buy-in (7 mentions): Respondents mentioned the need for “support and enthusiasm,” both from the people essential to running the project at the practical level (e.g., lab prep staff, other tutors and teachers in large courses) and from colleagues and supervisors whose opinions mattered to how the course was valued and sustained. One respondent noted essential support from “a technical staff member who is excited by the prospect of being involved in a research project,” while another noted challenges in “convincing some staff that this type of authentic learning is worth the time to do.” One respondent noted lack of collegial consultation as a barrier that prevented the spread of ALUREs in her school: “My school was initially enthusiastic about implementing more research-based experiences after hearing from students involved. However, these were started without consultation with the current ALURE teams, so there was no knowledge transfer and they have not continued.”

External support from the ALURE team was also important. One described the team as “...Brilliant! Nothing was ever too much trouble. So willing to share ideas and experiences and offer assistance.” Another noted, “Without help [from the ALURE team], what I originally planned would have been a disaster.”

- Time (5 mentions): Extra time was needed to develop the ALURE project and student materials as well as to teach the ALURE, at least initially. Said one respondent, “I spend a LOT of time on this—far more than my other teaching contributions.”
- Logistical issues (3 mentions): These issues were often context-specific, such as navigating the academic calendar to fit an ALURE into an 11-week term, or arranging for the ALURE to have dedicated use of certain equipment. One adopter noted the challenge of aligning the ALURE to experiments in the non-ALURE stream, as required by his/her institution.

- Student resistance (1 mention): Student resistance was seen as a challenge that was mitigated with time, as cohorts of students passed through the course and it became seen as normal.

These supports and barriers are similar to those cited in the literature for implementation of other teaching-related reforms. It is striking that, at least within this sample, financial support was most often mentioned as a support—that is, a resource that had been obtained—rather than a barrier, though funding was also noted as impermanent. The low prominence of student resistance is also noteworthy, especially since collegial support was noted as both a support and a barrier. This suggests that the adopters received good advice about how to plan for and overcome student resistance and other student-related challenges, such as scaffolding student work, that may lead to resistance if poorly handled.

The same kinds of supports and barriers are also raised in adopters' responses about the sustainability of the ALURE in their setting. Three respondents felt that the prospects for sustainability were good, citing top-down administrative support, bottom-up staff support, and student success as factors that supported sustainability. One person advised forming deliberate linkages among multiple ALUREs so that the student experience is scaffolded and learning objectives support each other across the courses. Their statements on sustainability were:

- Maintaining the present course (48 students) should not be difficult as long as the School continues to support it. A similar research-based (but non-ALURE) practical course for third-year students was abandoned this year because of the pressure it placed on research staff from the hosting lab. ALURE streams... have to become part of the courses, not just trial add-ons. If there are ALURE projects in multiple courses, there should be some mechanism to support each other rather than kept as separate parts of separate courses. Because these require extra personnel and cost more, there will also be pressure on them.
- The outcomes were positive and the program fully supported by [a key administrator], so these units will be supported into the future.
- [Sustainability prospects are] Extremely high. Students gain a lot from these experiences as evidenced by their reflections of the process and the project. The experience for the teaching staff including myself has also been an amazing journey. It has been a little extra work but so worth it! Watching the students take charge of their learning and making all the decisions—hard sometimes not to jump in and just say, “No that won't work”—you have to let them discover on their own.

Two other responses cited more tempered optimism about sustainability. They highlighted the importance of individuals, whether those who provided support from the top for the concept and the needed resources, or the bottom-up supporters who invented or worked with ALUREs.

- [Sustainability prospects are] Good, provided teaching workloads don't increase. If they do, the ALURE would have to go.

- [Prospects are] Dependent on individual course coordinators. We have some very successful ones, but not much incentive for people to put the time in to develop new ones.

Finally, two adopters offered additional comments that focused on the personal and professional benefits they had experienced:

- One of *the* best teaching experiences I have been involved with. Not only the project but the support given from the ALURE team to both staff and students participating in the project. This project has provided many other teaching-related opportunities for me... awards, attending workshops, presenting at conferences and implementing new ideas in other units on a smaller scale.
- It's great, and I'm encouraging other academics to get involved in developing ALUREs.

These comments speak to the intrinsic rewards (and sometimes extrinsic rewards too) of this kind of creative and integrative teaching work. Enthusiasm and enjoyment of the participating academics are key in initiating, expanding and sustaining these efforts, and cannot be mandated from the top.

3. ALURE Developer Team: Lessons Learned

The ALURE team is capturing many of its insights in manuscripts and practical materials. Here I offer some comments on their findings and call out some of the important themes in the insights that they have shared.

3.1. Evaluation Methods

For the summative evaluation, I interviewed the five core team members, Rowland, Lawrie, Wang, Zimbardi and Myatt, who recently moved to Griffith University, over Skype. The semi-structured interviews were conducted in a conversational manner and focused on three main topics: the current state and sustainability of ALUREs in these leaders' units; the insights gained from supporting new ALURE implementers; and their views of whether and how they could continue to support ALURE implementers after the grant's completion. Interviews lasted 35-60 minutes and I took near-verbatim notes, from which quotations are drawn. I also drew extensively on the documents listed in Section 1.2.

3.2. Student Outcomes of ALUREs

The team has carried out substantial evaluative research on student outcomes of its original ALUREs, and of those at some adopter sites. Evaluating the latter sites is a somewhat unfair proposition, as initial runs of a course may not be as strong as later editions that have benefited from formative evaluation and instructor experience, and drawing conclusions is more difficult when sample sizes are small, as is often the case in pilot courses. Nonetheless, this provides useful learning as long as the constraints of such analyses are understood and not seen as summative or final results.

The resulting data from a variety of sources show that students make significant gains in laboratory skills and in general skills such as time management and teamwork. They gain confidence and are more resilient to the frustration of failed experiments and the tedium of repeating them, and have a better understanding that some failure is a normal element of research. Moreover, this taste of research seems to be enough for many to decide whether or not they want to continue in research, which means that students' choices are better informed (a kind of clarity that students universally appreciate, whether or not they continue in research). Those who do continue to an apprentice-model UR experience in a laboratory may be more committed and better prepared.

In general, student gains from ALUREs are more strongly positive than those noted by students in the non-ALURE ("LEAPS") sections. In one case where the ALURE implementation was more tentative and student independence was more constrained than ideal, the reported gains of ALURE and LEAPS groups were still quite similar. While this demonstrates that ALURE outcomes are indeed sensitive to the quality and enthusiasm of implementation—this is not a plug-and-chug educational intervention—this result is also perversely encouraging because it shows that no harm was done, even when the new ALURE was still in a work in progress.

I agree with the team's characterization that many of these outcomes are similar in *nature* to those gained by students in traditional semester- or summer-long apprentice-model UR experiences. However, there is no evidence (from their or anyone else's work, to my knowledge) to indicate whether these outcomes are comparable in *degree*. Numerical results for student gains measured by instruments such as the URSSA cannot be directly compared; the very experience of doing research means that the scale endpoints shift as students' self-knowledge and self-assessments change. Indeed, it is well known that self-assessment is more accurate the more people gain experience with the domain and get good feedback; in these research-related domains where students are still novices, the meaning of the domains is still shifting. I urge the team to read and interpret the literature critically and to be precise about the claims they make in their own publications.

3.2.1. *Why does gathering outcomes data matter?*

Several project leaders discussed ways that student outcomes data had shaped their work and influenced others. Certain kinds of data were seen as persuasive because these data documented outcomes that are especially valued by scientists. For example, one team member noted,

[From here forward we will do] less in-depth assessment of the student outcomes—but from the past 2-3 years we have enough data. The students are benefiting. We see them grow in science skills—and the increases in their confidence in their skills, we see that every time. Also it improves their awareness of what a research pathway looks like. That is important for me in teaching a second-year course: I want them knowing what is beyond this course, what the researchers actually do. They are thinking like a scientist. [I see changes in] how students perceive the data analysis, the critical analysis.

(continuing) [This particular ALURE] generates a crazy amount of data, when we combine results from couple hundred students. So it really forces students to recognize that the big data revolution is here, [learn] how to organize and explain data. It's trial by fire! But at the end of the class project a significant portion of them can really grapple with the big spreadsheets we generate.

Another team member likewise described the process used to gather evidence on student outcomes and the kinds of outcomes thus documented that were important:

We always wanted the objective evidence to show that the students are meeting outcomes. I have clouds of evidence that we have not analyzed yet! [We got a lot of information from students] by asking open-ended questions: How do you learn, what did you learn, what are your strategies? Tell us one thing you learned, and one thing you had already. And then we got more specific in the questions.

(continuing) The students learned to critically evaluate literature: given a specific method and study, what are the questions we can ask? They were better at looking for the overlaps among studies than the gaps between them; this is more robust and easier to do. Most students are at the level of finding gaps in the methods and results; it is harder for them to find gaps in the conclusions, in the overall story of the research field. And some students at the end still have an idea that it is about finding the papers, not reading them—they are convinced the answer must already be out there somewhere. But [in doing this] you change the nature of the conversation on the nature of science. The videos were good on this—[the video data show how] students' discussions change in complexity, their use of evidence; how they think about the literature, their critical evaluation.

These quotations highlight several important aspects of how the team did its work, which are also evident in other data sources. The team used careful collection of student data to support their claims about the benefits of ALUREs, but also to pinpoint what is reasonable to expect of students. Course expectations can then be set so as to push students—while recognizing that even those who fall short of those expectations will still grow in meaningful ways. Team members' sense of what is reasonable to expect is not arbitrary but guided by the data, and therefore can be more persuasively communicated with new adopters. This theme of getting the level of challenge right continues in the next section.

3.2.2. An essential design principle for ALUREs: Challenge vs. support

The team has learned some useful things about designing ALUREs to optimize student learning. The most important of these, in my view, is to find a “balance between autonomy and distress,” as one author put it, that places students in a position where they must stretch to achieve the course goals yet in doing so gain useful skills and knowledge and a strong sense of accomplishment. In some cases finding the balance means reducing distress by providing more

support, as in this example of how lab work was structured to give students more confidence in their results:

This year we grouped [the lab teams who had the same samples across lab sections] so that they could share results and literature. They don't believe their own results; they don't trust their hands. We wanted them to see that when three groups got the same result, it's not just a fluke. They were encouraged by this as reassuring. [The present cohort] are doing the analysis now. Right now I am getting the right kinds of questions from this group—so I think they're getting it.

More often, however, the challenge for implementers was not to support but to back off—to leave more room for students to make decisions and to face the consequences of their choices.

When [my colleague] saw the data, and saw what students could do—now she does it really well, but the first year the room the students had to move was a little too tight for me. When you see what students are capable of, you up the ante. We push them more.

(continuing) ... There seems to be a tussle, a choice to make, between authenticity and ownership. The more you need the supervisor to help with the science—because they can do it fast, make the decisions—then the students can get some results. If you give the students the ownership, they won't necessarily find the gap or design an appropriate method to fill the gap. So then the experience is more about inquiry, the results are not novel—it's less authentic in the outcomes but more authentic in the scientific processes.

(continuing) For example, optimizing the protocol, this is a classic thing to do [in a research-based course]. There are lots of choices there. What outcome should you look at? What conditions? I have had the experience of making sure the experiment will work before we put it in student hands, say, using a PhD student to optimize it first. But now I'd say, give it to them half done – 'Here's what we know already, here's what we don't know.' It's more like what happens in a lab. It does not have to be perfect—as long the students have something to write up at the end. Can they argue why it happened?

(continuing) How do you convince colleagues that if they let go it will be awesome? For some it is open-mindedness. For some it can be student outcomes [that are persuasive]—you're more cautious the first time, the space for inquiry is more restricted. When they see the students, how good they are, that can be the catalyst. It can reassure, help them see it's OK to trust the students.

This long quotation highlights that in general students will rise to the occasion and meet the challenge, as long as the task is appropriately framed and scaffolded. Data and personal experience can help to persuade instructors to let go of the reins a bit and give students a sufficient level of challenge. Indeed, too much support could be as great a problem as too much challenge, as one speaker noted about a particular course:

The students were super well-supported—and all they could do was complain. It was a learned helplessness. The outcomes [we measured] were very different. It is possible to over-support students—but you can't do that if you want them to do something authentic.

Another speaker elaborated on this point, describing how the level of challenge must be adjusted for advanced students. Coordination among courses was even more crucial when multiple ALUREs were offered in a program.

Students who have not done an ALURE before take ownership; they talk about that. For third-year students who have done two ALUREs before, it is starting to lose its gloss; they are becoming jaded. We start to hear, 'It's not real, because they can't let us fail because we are undergrads. They will bail us out.' So to keep them engaged, we must up the level of risk. They are savvy, they have figured out that there is support. They seem to need a greater level of challenge—we can't in fact let them fail out, because they don't really have time to fail and recover. The ALURE is a contracted experience; they don't have time to fail deeply, and they know it.

The speaker went on to characterize how this need for appropriate challenge also shaped when and where course-based research opportunities should be offered within the curriculum:

I would like to see everyone do an ALURE once as an undergraduate—but not for every student in every course, or even every year. Different units will have to do it differently. Is there a best place for it? [Early on] it is good as an extension activity, with self-chosen students. Everyone is happier this way, when they can choose—it is good to choose when you are in first and second year. In the third year it needs to be very challenging. [One of our third-year courses] works really well, because it is difficult for the students to choose what path to take. They have to consult with more senior scientists; they have to argue, they have to be overwhelmed for some of it. There is a proximal zone of development here. They are in a frazzle—we have done a lot of work to get them this far, but they are still in a frazzle at midterm. This is normal! If you knew the answer, you would be bored. The sense of being lost is really important.

The rewards of getting this balance right were evident. For example, students felt strong ownership of the project, which in turn led them to invest more time and effort:

The best part of it is that they run [a certain assay], they do lots of pipetting—this is the phenomenally boring technical bit, but the students loved it. It really helped me to reinvigorate my own enthusiasm. They repeated it over and over; they really wanted to make it work.

These elements of challenge, support, and ownership also relate to relevance or students' experience of authenticity. The team has backed off somewhat from its original view that authenticity meant that students should be doing original research that contributes scientifically, and in my view this is an appropriate choice to value the scientific process and worry less about

the results. Implementers have found other ways to introduce the relevance that students need to engage fully. As one speaker explained,

We have made compromises on the scientific goals—most likely students won't produce publishable stuff. Their skill is not good enough. If you want them to produce publishable data, you have to control too much. You can't do that if you want them to learn something. Then you just have a bunch of little robots.

(continuing) They do need a real-world context. They need to think it's important, whatever they are doing—even if it is pretty heavily controlled. [For example, in one course] they are purifying a protein. There is a known protocol; you can't just make up a new purification protocol—but they have a reason to do it; this particular protein is a new application for agriculture. For the Beer and Biofuels course, they like that; they are interested in beer, or in the environment. In the Microbiome course, they are always finding parasites and other lovely things. [Some of these are disease-causing]—so it's personally relevant.

These kinds of observations about the balance of challenge and support, ownership and authenticity, also support the team's choice to place less emphasis on formal communication of results to external audience. Nonetheless ALUREs include these opportunities when available, as well as other tasks that move students toward professional communication practice.

3.3. Supporting Adopters

The team has already captured much of their wisdom about instructor support in their worksheet-like checklists and exemplars and in forthcoming publications. Here I highlight a few key features that explain how they do this effectively. First, their emphasis on design pays off by supporting people through the hardest part:

[Implementers] realize the up side of doing this, and we are there to walk them through it. So this makes it not impossible. An ALURE is seen as workload-intensive. [As we go] there is a bit of realization that the effort is in design, but less in running it, if you design it well. It is engaging for them—we have gotten some busy researchers involved in it that I did not expect. People are willing to engage in it more than we thought, if they understand the process of design.

One speaker explained their ways of working with adopters, and why these were effective:

What have I learned? For one, you have to let people do it in their own time. It can take a lot of time. They have to negotiate a lot of things to make it work, including some self-negotiation—resistance, time. Second, the best way to support them is to go *be* with them, help them work their way through their problem. There are a lot of little barriers, but if you are there you can help them: 'Yes, we can solve that; yes, that one is harder, let's think about it.' Once you are there, and on the end of the phone a few times, after a year they are quite self-sufficient. We now have two groups of people who took it up,

and they are now mentoring others, they have become the person on the ground. They are doing it; I don't have to be there. It is still ballooning here at UQ; people come to talk to me here. But there is someone on the ground [in other places] who can help us do this.

Other factors that fostered success—particularly when the team gave a workshop at another institution—included time set aside (1-2 days) to focus on ALURE design, which becomes a higher priority when a team visits from another campus; and an invitation issued by a change agent (e.g., senior academic or administrator) who has “quarantined” that time for faculties to work together. As several commenters noted, the face-to-face time was important.

The web site – the wiki to build the community of practice—did not work. People are too busy. There has to be a purpose to go there, not just information retrieval, but something more dynamic, something to do when you get there. People wanted a conversation. It's different [than we thought], but a nice outcome really.

What is most surprising should not be surprising. The online community of practice did not work. There is a lot of gumpf around online learning communities—is it generational, is it another skill set? But this was all about relationships. ... You had to have relationships, talk with people face to face, build trust. It's not about resources, processes, and a how-to booklet. If you wrote this up in the proposal—that the goal was to build trust, build relationships—you would not get funded. So the main learning is for the granting bodies: You can't just build online communities of practice and deliver resources. It was not what we expected, but it should not be surprising—that is how so much of the world works.

The team composition was clearly another source of strength. Describing the workshops at HERDSA, where multiple talks were combined into a joint session, one leader said:

[The multidisciplinary team] helped because someone different could answer the same question with a different answer, from a different context. The differences between them was helpful, the disciplinarity. Are there multiple ways to do it right? Yes. The ALURE can be different in different disciplines. Someone might say, ‘It costs too much. How can it work for me?’ The presenters could say, ‘Here is how we got around it,’ each speaking from different points of view, so there is more credibility. People can't use the excuse that ‘My discipline is very special; you can do that but I can't.’ They just heard three answers that say, ‘We can do this in chemistry, microbiology, physiology.’ So it's harder to argue that this is not possible in my discipline X. The team was strong in this respect.

Another speaker noted the important role of students as participants in the project, analyzing research and evaluation data and helping to work with adopters. “The students have been a great advantage—to have student involvement, student as change agents, on the team, doing Honors projects. They are valid contributors to the team.”

The adopters were nearly unanimous in indicating that they do not find the implementer support work onerous, and most feel they could continue this on an informal basis without grant support.

It's not a lot of effort. You have to be the friend on hand, the critical friend a phone call away, so you can touch base with someone to help. For lots of people, the kick-start, the shove on the bicycle if you will, is enough to get them going. We haven't had a lot of high maintenance people. And the students on the project have done some of that.

They saw ways to keep up the ALURE work over time, by recruiting through their own disciplinary networks and routine presentations at conferences such as HERDSA and ACSME. In some cases other institutions had supported the team to lead a workshop. "It doesn't take a lot of money, and it doesn't have to be the same ones of us every year. Through the contacts we've already made, we can recruit other new ALUREs," noted one team member. "The new people are the best recruiters," noted another. "When we help others, they in turn become the next recruiters. We give them kudos and credit." While I have some concern about already-busy academics committing to still more unpaid labor outside their institution that may be viewed as low-status "service," I also view this kind of work as appropriate and needed leadership for a growing ALURE community in Australia, and I recognize that there are likely to be professional rewards for it as well. I applaud the team's willingness to continue.

3.4. Sustainability of ALUREs

UQ itself provides the best test of sustainability, as the ALUREs there were established some time ago now. At present, the ALURE concept continues in some form in all of the founding units at UQ, although with varied degrees of enthusiasm. In some cases the original ALUREs are ongoing; in other cases the original versions have been discontinued and replaced with other designs; in still others the overall number of ALUREs has increased. The first test for sustainability is whether the ALURE course can be handed off to another colleague to teach:

For me it's normal to work in chaos, with 70 students in the lab working in groups of three, all doing slightly different experiments, and you help them find extra equipment and solve their problems. Once the tutors were not sure whether to do a t-test or an ANOVA; I had to help them understand that it's your data that tells you which one to do—there is not a rule, your data tells you! This is normal to me [as a way of teaching], but it is not to everyone. [In handing off this course] I realized that not everyone can pull it off. Some people have control issues. An ALURE should not be forced on others. Some are better off if they run a recipe prac. Because when it's not done well – it is worse than a recipe.

A number of factors were cited as supporting sustainability. Interest from other colleagues, and especially enthusiastic help from the laboratory preparation staff, was crucial not only in keeping ALUREs running but in generating new ideas to refresh a course or invent a new one.

[To make this last,] the school is realizing—and the labor market is pushing this way—that the people who are in the prep lab can't just be run-of-the-mill people who want to

follow directions. Our new appointments in the prep lab all have PhDs; they are keen to build activities, to develop experiments. They are serious scientists with publication records. It is a tragic reflection of the job market here, but it's good for us. These people raise the bar in terms of developing stuff in the labs, and this helps with sustaining it for the students. It is a culture change. It *is* sustainable, but because of them.

Another speaker described how engaging researchers in applying their specialty to an ALURE had expanded possibilities in her unit:

[One colleague] came to HERDSA and presented her implementation of ALURE. She is a traditional academic, [not teaching-focused]. She did a good job; [among other topics] she talked about benefits to her as an instructor. For me this was an affirmation of the sustainability of the model, and the momentum it has [in this program].

Another interviewee likewise saw the research linkages as fostering sustainability:

What has surprised me is how the research linkages continue. We still have research results coming in. From the researchers' perspective it has remained fresh, though we will slow down the student evaluation [now that the grant has ended]. ...The samples are still in the pipeline for publication as research, but we have a teaching paper published.

This speaker continued:

This is a big hook for our major. Everyone above me really likes that we tie in research. How many years can we extend it depends on the technology—if [the techniques we use] become cheaper, it is more sustainable. It will go on for a few years at least. Every single higher-level course [in my unit] is trying to put a research element in, where students are doing something that is real research—our unit is quite a success in this respect. I'm the major convener, so am involved in all of them. It is a role of responsibility and influence.

All these quotations speak directly to the importance of people in a variety of roles in sustaining ALUREs: researchers who are eager for the results and for students interested in their field; laboratory support staff who see the value of inquiry and can help devise creative solutions for supporting these experiences on a large scale; coordinators and conveners who can organize the team and maintain coherence; senior administrators who place priority upon and signal to others the value of these experiences and who support them with the needed resources.

Another part of sustainability is marketing, or making the case to the institution to garner the needed support. Some interviewees discussed the kinds of messages that appealed to potential adopters. The ALURE team offers a consistent and non-elitist message that these outcomes are valuable for all students, not just future scientists. One speaker emphasized this point:

[All of our applied science majors] benefit from an understanding of where facts come from, how evidence is built, how it will change. So if they ever want an answer they can go find it—they don't have to rely on the sales rep to tell them, they can go to the primary

literature and get it. The skills developed in an ALURE—whether it is ‘real’ research or more of a guided inquiry project—to come up with hypothesis, to deal with the decisions about your experiment, it is beneficial to all students to do this.

The team had not noticed particular patterns in who was successful in implementing ALUREs, but they did notice that success depended on the kind of support adopters were able to recruit.

We see a wide range of implementers. It is not so much about what type of academic, but rather, if they want to do it, there is someone higher up in the hierarchy who can support it. For example, some heads of department have come on board and said they will help. People do need buy-in from higher-ups to go forward... this matters a lot. Also it is important to sell it in a way that some key outcomes align with what the institution is interested in. For most universities in Australia, it is not too hard to sell the research-teaching linkage of undergraduate research. Rather, the resources, the implications—this is where the hesitancy arises. The project helps to deal with [issues like that], the ins and outs.

Another interviewee took this idea further, noting that research-based courses may be framed differently to align the ALURE model with varied institutional priorities:

You can look at the ALURE model in two different ways. One, it provides an effective learning environment for students. Any university that has a strong focus on teaching and learning for students, that documents its graduate attributes, that values critical thinking as an outcome for students—then you can sell ALURE for that goal. And if the institution has a strong focus on research, you can turn it over and say, ‘This is giving a research experience to students.’ You can sell it that way to a research university in the Group of Eight.

In turn, access to an ALURE might make a bigger difference for students in some places than others:

[In any institution] several hundreds or thousands more students a year now have a research experience who did not before... I don’t know how many it really is now. But this is especially important in places that are less rarefied than UQ, more the real world of higher education. [At less elite institutions,] the students have real problems, the teachers are less supported. At UQ, teachers have to be innovative to survive; but at other places they just survive.

This comment is interesting in that it flips conventional logic that research-based teaching will most easily take hold in an institution that already prioritizes research. Rather, this speaker noted, an ALURE may be seen as more valuable or profound at teaching-focused universities where apprentice-model UR opportunities are more rare. This would be an interesting hypothesis to document and analyze in future work.

4. Recommendations

Because the project is complete in all but the dissemination phase, I focus my recommendations on the products of the project. I very much look forward to the team's forthcoming scholarly publications, especially those on the process of teaching ALUREs and on helping others develop them. I have offered my support in reacting to drafts and helping them find publication venues.

I am also glad to see some emphasis on practical products. The checklists are very good, and attractive to boot. I like the worksheet format very much, and I find the embedded questions and tips concise and thought-provoking. I would love to see an explicit connection between the Motivation and Values checklist and the Evaluation checklist, as motives and values should shape some of the evaluation choices. The advice to dial back expectations and not try to gather evidence on everything at once could be even stronger, and it would be good to include some simple formative feedback mechanisms, such as the roses, buds, thorns reflection that the team has promoted.

The exemplars are less appealing to me; they need a good proofread and some dialing back of jargon, and I found it harder to identify their common structure. In my view they would benefit from greater consistency in the headings and layout. I liked the use of the developer's voice, but this information did not always speak for itself. Therefore I wonder if there would be benefit in calling out the general lessons or principles, to answer "so what" or identify consequences of some of the course design choices. Ideally these call-outs would align with the checklist questions, so that a reader considering an ALURE can see more easily how various authors answered certain checklist questions, or what different sets of design choices might look like. In some cases the course goals seemed quite generic, and I'd like to see some sharpness in identifying for a non-specialist what parts of the project were open and what was pre-structured or bounded for the students, as I think this is one of the most important design features that the ALURE team has highlighted. Perhaps these documents would benefit from a carefully structured one-page cover sheet to highlight general features before plunging into the technical details. I would also love to see more of these from a wider array of disciplines and target years. That said, I do think all these materials have the potential to be a very useful resource to adopters well beyond Australia, so some attention might be given to vocabulary that is context-specific (or even a short glossary provided!).

To support these materials as they deserve, the ALURE project web site needs a major update, with the new implementer support materials posted as soon as possible and highlighted boldly. Some reorganization of headers and sections may be needed to archive old material and highlight what is new, and one-stop shopping for an up-to-date publication list from the ALURE team is imperative. While it takes time to get all the work organized and published, ultimately the combination of practical resources with solid scholarly backing, along with the team's intended efforts to continue presentations and workshops, should be effective in further enhancing classroom practice and professional community around ALUREs in Australia.

5. Conclusions

Overall the project has met its goals and has done so with style. The team learned as they went and made appropriate adjustments to their tactics. The team's work is of high quality; they appreciate each other, and they are thoughtful and self-critical. I learn a lot from talking with any of them. Based in the US, I am less able to assess the project's impact on the Australian higher education landscape. However, I think the team's approach to course design, their conceptualization of the balance between student support and challenge, and their insights about implementation are as good as any work with which I am familiar in the U.S., and more advanced in several respects. I recommend their work often to colleagues here.

In closing, I offer these self-assessments from the leadership team, which focus on the teaching and learning experience offered by ALUREs, the process of change, and the net impact of their work.

The most important thing is that [an ALURE] is fun—for the academics, for the students. It's what learning should be.

What is the project's best accomplishment? It has raised the profile of UREs as an accessible learning environment for large numbers of students, by sharing why this is a good idea. Now people know about a thing they would like to do. They might not be able to do it yet, or have the support, but there are more people doing it, more champions. There are more students doing it, and their experiences are getting better. There is recognition of staff who are doing this kind of thing—the improved student experiences stem from better teaching and learning practices. Those advocates become encouraged in time. The academics who do this are important.

We talked to a lot more people than I thought we would get initially. I have seen a culture change at my own institution. I think the others will experience that too, eventually. [They are earlier in the cycle.] That has been a really good outcome for the project. I personally believe in this, and it aligns with how I would have liked to be taught as a student. The people are passionate about it; they are more engaged than I thought... it is more successful than I thought it could be. The people running ALUREs are engaged, enthusiastic, and it has really affected change at a level that I had not anticipated.

I have learned a lot about how people negotiate ideas, negotiate change within organizations. It has made me happy to see how people do it in a constructive way. We'll remain friends and colleagues for a long time.

The project has wrapped up and we have accomplished a lot. I'm keen to see what we do next!

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