APCELL: Developing better ways of teaching in the laboratory

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Abstract: The Australian Physical Chemistry Enhanced Laboratory Learning project was established to address deficiencies in Australian physical chemistry laboratory education. The project aims to pool the resources of over 30 universities to develop a protocol for developing and assuring the quality of laboratory teaching experiments. This protocol is based on 'research-led teaching' and is underpinned by education research literature. Because of its grounding in research, the project has demonstrated the potential to generate and support further research on teaching and student learning in laboratories. In this paper we describe the progress of the project to date and some of the research methodologies that have been employed.

Introduction

'Research-led teaching' and 'scholarship of teaching' are phrases that are increasingly being heard in discussions about teaching in Australian universities[1,2]. The current focus on research-led teaching exemplifies various trends and changes in Australian and international higher education[3]. The use of the terms is, in part, a reflection of the increasing recognition of the scholarly and professional nature of university teaching as an added dimension to the disciplinary expertise of academics. The focus on research-led teaching supports, and is supported by, a growing body of research literature on teaching and student learning. At a more pragmatic level the interest in 'research-led teaching' reflects a university strategy of building upon established research expertise and performance in the increasingly competitive teaching quality market[4].

The Australian Physical Chemistry Enhanced Laboratory Learning (APCELL) project is a nation-wide teaching development initiative coordinated by academic staff at The University of Sydney and The University of Adelaide and involves 33 Australian universities (and 1 New Zealand affiliate) that teach chemistry at the undergraduate level. Experiments in the laboratory can provide students with some of the most effective and valuable learning experiences of their courses. Research-led teaching is being used within the APCELL project to address shortcomings identified in laboratory-based student learning.

The term 'research-led teaching' has assumed various meanings in the context of discussions about the scholarship of teaching and scholarly teaching. Amongst other things 'research-led teaching' can refer to:

- **the use of disciplinary research in teaching** – for example, the use by a teacher of one of their current journal publications reporting a key piece of cutting edge research;
- **teaching and curriculum that uses evidence derived from research and inquiry** – for example, designing an assessment task on the basis of published education research or one's own inquiries into how students approach particular assessment tasks; or
- **research into teaching and learning** – for example, a research investigation into how students approach different assessment tasks.

The APCELL project can be described in terms of each of these aspects. Primarily the project is an example of the second category of research-led teaching – a teaching and curriculum development initiative that is based on research. However, not only does the project draw upon the results of previous teaching and learning research in terms of the teaching and curriculum design which is at the

core of APCELL, but the project methodology also uses the processes of scholarly inquiry into teaching and student learning. Moreover, the products of the APCELL project have the potential to generate and support further pedagogical research, (the third category above). As the project also aims to incorporate the results and topics of current research in the undergraduate chemistry laboratory curriculum it also demonstrates the first aspect of research-led teaching.

This paper will describe the processes and outputs of the APCELL project in terms of these three different perspectives on research-led teaching. In doing so it will seek to demonstrate the key facets of research-led teaching and highlight aspects of the APCELL project which may be of interest to other university science teachers.

History of APCELL

Almost all Australian universities teach chemistry at the undergraduate level and over 20,000 students per year pass through these courses. Physical Chemistry, a critical component in all of these courses, is highly conceptual and many students find the subject matter difficult to grasp. Laboratory work is integral to all Australian chemistry curricula (the Royal Australian Chemical Institute (RACI) requires universities to provide 350 hours of laboratory work for students per year to gain the Institute's accreditation for chemistry courses). Experimentation in the laboratory can help make concepts introduced in lectures meaningful and provide students with some of the most effective and valuable learning experiences of their courses. However, this promise is not always fulfilled.

From the mid-1990s, academics meeting at research conferences around Australia began discussing anecdotal evidence that an increasing number of students were finding their physical chemistry laboratory courses to be uninteresting and unmotivating. As learning experiences, they needed to be improved. These informal discussions highlighted a widespread recognition amongst academics that students studying physical chemistry are not learning in the laboratory as well as they should, or could. Reports of individual institution's attempts to improve learning in the laboratory were prominent. However, it became apparent that no single institution could overcome the multiple barriers to learning, which are imposed by limited physical resources, limited specialist expertise, limited pedagogical expertise and limited active student involvement. It was agreed that a collective effort involving the resources of multiple institutions was required to overcome the problem.

During late 1998 and early 1999 Barrie, Buntine and Kable developed a proposal to improve student laboratory learning outcomes. The proposal, involving over 30 Australian universities, was submitted to the Committee for University Teaching and Staff Development (CUTSD) for consideration for funding. Initial seed funding from The University of Adelaide, together with extensive institutional support from The University of Sydney were critical in the development of the proposal. This proposal, the APCELL project, was designed to solve the problems in student learning in chemistry laboratories across all Australian universities. In late 1999 CUTSD approved APCELL and the project began in early 2000 with the appointment of Jamie as Associate Director.

APCELL has brought together diverse physical chemistry educational expertise and resources from across all Australian universities and is developing a protocol for the design of teaching experiments based upon sound pedagogical tenets. The result will be a suite of experiments that will facilitate improved student learning, taking into account the widely varying backgrounds and needs of students from different institutions. In effect, APCELL is overcoming the resource constraints of individual university chemistry departments by treating the participating institutions as if they belong to one large department.

Research-led teaching

The APCELL project is an example of the typical research and development spiral familiar in many industries and academic research disciplines. However it is less familiar in teaching and curriculum design (see Figure 1). The box outside the spiral represents the initial formulation of the APCELL plan, which was based on the results of an inquiry into student learning, conducted from the student experience perspective[5]. Data were gathered on students' perceptions of their teaching and learning experiences in laboratories. These data indicated that student laboratory learning experiences are not always perceived as being relevant to students' learning needs or particularly effective in supporting students in achieving useful learning outcomes. This finding supports that of numerous publications on 'effective laboratory teaching'[6,7]. This realisation prompted an inquiry into the nature of the barriers, 'why hadn't the required changes been implemented?'. This inquiry gathered data through consultation with colleagues in other chemistry departments and colleagues in curriculum development units as well as a consideration of the literature. The data indicated that resource barriers posed a serious barrier to such curriculum review, re-development and renewal, as did conceptions and approaches to teaching on the part of some teachers. In planning a strategy to overcome the barriers and address the problem identified in the student data, the project team drew upon the research literature on laboratory teaching and learning[8] and the research literature on curriculum and academic development[9] and curriculum change.

The methods employed in the APCELL project were selected on the basis of the research literature in the field of change management and academic development[9]. While there were numerous publications that espoused excellent practice in designing and teaching in laboratories, these did not appear to have had much effect. The project therefore planned to engage academics in reflecting on their own curriculum decisions about teaching and design of laboratories[10]. The project method identified the need to engage participating academics from the 32 different universities, at the level of their underlying ideas about teaching and learning, rather than at the level of teaching behaviours. The project aimed to use processes that would encourage participating academics to design their laboratory teaching from a learner-focused perspective rather than a teacher-focused perspective. This strategy required that the project start with the participants' own ideas and conceptions of teaching, even if these were teacher-focused, and reflect on, and challenge these, in developing the parameters for the laboratory curriculum template. The template forms the core of the APCELL project. Rather than prescribe 'good' teaching practice, it aimed initially to promote a consideration of existing teaching practices from a learner-focused perspective[11].

The development of the parameters, or criteria, that were embodied in the 'template' was the first stage of the process. The second stage of the process was the development, submission and review of laboratories for inclusion in the APCELL database. This culminated in a workshop where staff and students from the participating institutions came together to engage in an inquiry into the student learning experience of the submitted laboratories. During the workshop both teachers and students participated as learners and both contributed 'learner' evaluation data to the inquiry into the laboratories submitted. At the same time the template itself was peer reviewed and evaluated as a tool to support the review process. These processes were themselves examples of scholarly inquiry into teaching and learning in that they drew upon data from teacher and learner surveys, collaborative review and academic peer review. At all stages the methods were focused on overcoming the identified barriers, and the choice of the strategies was intentional and supported by the relevant literature. At a more practical level, the project used its funding to pool the resources and equipment of the participating universities.

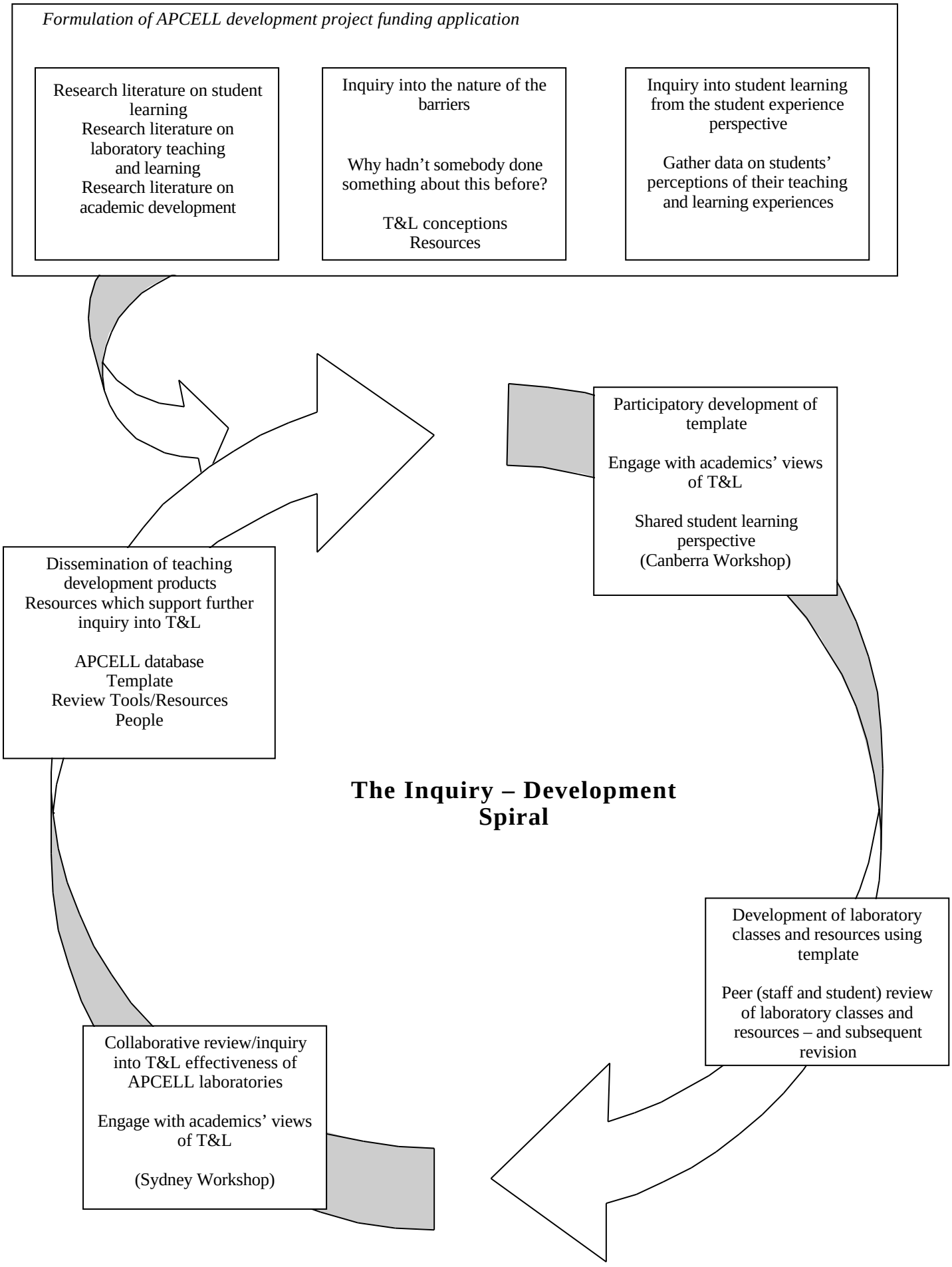

Figure 1. The Inquiry – Development Spiral

The next stage of the process will involve the dissemination of the revised template, along with the tools (student surveys, etc.), guidelines and criteria for the peer review and submission process and the experiment database itself. This will be published on the existing APCELL web site at http://www.apcell.org/. It is envisaged that these products will further support research-led teaching investigations and inquiries, both in chemistry and the other sciences.

The template prompts academics to reflect on their underlying rationales for designing and teaching laboratories the way they do. It brings to the surface many of the assumptions about teaching and learning that are the basis for teaching research and inquiry. By engaging in such reflection and documenting the outcomes as part of submitting an experiment, academics (who are by nature curious!) might become curious about their teaching as well as their research.

The review tools and resources include the staff and student evaluation review questionnaires used in the workshop and template, the peer review criteria, etc. The experiment evaluation tools have already been used by academics to investigate particular aspects of their own teaching unrelated to APCELL. These resources have also been used in the development of additional teaching and curriculum resources, for example an investigation of the effectiveness of a report template, which was included.

However, the most influential resource for further inquiry and research is the people who have participated in the APCELL project. The staff and students from the participating universities seem keen to pursue the ideas and new insights they have encountered in the APCELL process – more importantly, in terms of acting on this interest, they have a network of colleagues to support this.

The final evaluation of the effectiveness of the APCELL project will be commenced early in 2002. It is envisaged that this evaluation will primarily consider the uptake of the experiments in the database, and their impact in terms of improvements to the quality of the student learning experience. However this evaluation will also seek to investigate and report on the contribution of the project to research-led teaching, and the effectiveness of the change and development strategies it employed. In this investigation and reporting, the APCELL teaching development is, in turn, contributing to the research literature from which it grew.

Conclusion

Through using the research and development spiral as described above, the APCELL project has developed a protocol for preparing Physical Chemistry undergraduate experiments. The philosophy of APCELL and implementation of the protocol have been accepted enthusiastically by a significant number of the Physical Chemistry teaching community and the project is leading to the production of a valuable resource for that community. The research-led teaching methods employed in the project are applicable to all areas of laboratory-based education and it is envisaged that the project will be expanded beyond its original compass.

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