Significance of laboratory experience in undergraduate microbiology

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The 2008 *Review of Australian Higher Education* [1] highlighted current financial constraints on higher education in Australia that impact negatively on the quality of student experience and their learning outcomes. Practical laboratory experience is costly in providing venues, staffing, materials and equipment. However, the practical nature of microbiology necessitates acquisition of significant knowledge and experience of laboratory skills to effectively support the profession. This article provides evidence that inclusion of practical classes in undergraduate microbiology courses has multiple advantages: quality learning facilitated through experiential, engaging learning activity; undergraduates in theory plus practical courses achieve significantly higher results than those taking theory-only units; and student feedback that articulates that laboratory experience facilitates quality learning outcomes.

Engaged interactive learning during microbiology practical classes.

The recent 2008 *Review of Australian Higher Education* [1] found that:

> *Australia is falling behind other countries in performance and investment in higher education [and] there is abundant evidence that government provision of funds for underlying infrastructure to support research in universities is very significantly below the real costs…leading to…cross-subsidy from funds for teaching, adversely affecting the quality of the student experience.*

Alarmingly, Australia is the only OECD country where public contribution to higher education has remained at the same level for the 10 years: 1995 to 2005 [1]. The promise of the current Labor government of an education revolution has had little impact in the current global economic crisis and universities remain increasingly dependent upon income from international student registrations [2].

With these financial constraints on tertiary education, it would be tempting and arguably understandable for universities to make the strategic decision to reduce expenditure on undergraduate teaching of costly laboratory sessions that require specialist venues and infrastructure, significant technical and casual academic staffing, equipment and materials. However, the Australian Learning & Teaching Council recognised the importance of practical experience when it recently recommended a commitment to the inclusion of laboratory work, specifically in first-year undergraduate science classes [3].

In this sensitive financial climate, higher education is changing with remarkable rapidity and functioning in "an age of supercomplexity", impacted upon by globalisation, digital technologies, competition, agendas of participation, access and equal opportunities as well as systems for evaluation of quality [4]. Academics are placed in a tenuous position in teaching undergraduates where the aim is to develop and foster skills that will equip graduates well for the workplace.

The case for incorporating significant practical components in undergraduate microbiology courses is supported by several aspects, which will be addressed in the following sections.

The inherent practical nature of the discipline of microbiology

Microbiology is a discipline involving significant hands-on skills of dexterity, accuracy and reproducibility for isolating, identifying and testing microbes, underpinned by the need for maintenance of aseptic technique. Furthermore, the ability to effectively perform molecular techniques in diagnostic, quality control and research contexts is contingent upon acquisition of significant practical skills. Such significant hands-on skills and an overarching knowledge of the theory of practical techniques and applications are therefore graduate attributes that are critical for a successful career in microbiology and necessary for application in its many facets: industrial, environmental, pharmaceutical, medical, food and agriculture.

The wet laboratory provides the learning environment for acquisition of this knowledge and practical skills. However, in a climate of increasing student numbers and decreasing tertiary budgets, evidence has been provided for effective learning outcomes using dry laboratory contexts such as case studies, problem-based activities, computer simulations and virtual laboratories [5, 6]. Nevertheless, Raineri [6] believes that "nothing can or should be used to replace the traditional hands-on approach to learning experimental techniques". By downgrading teaching of laboratory skills and aptitudes, the risk is run of a consequential skills shortage in the workplace, as is currently the case in the biosciences in the UK, both in the number of skilled graduates and the extent to which graduates are appropriately skilled [7].

Practical microbiology promotes quality learning

It is well-established that high-quality teaching fosters active learning through student engagement in ways likely to result in their understanding [8, 9]. Several studies have shown the importance of developing critical thinking skills such as problem-solving, developing concepts and experimental design [10, 11]. In microbiology, it is impossible to teach every possible technique and it is therefore transferable skills of reasoning and critical evaluation achieved through application, analysis and creation, that are important for today's graduates [5, 12].

Individuals learn in different ways using three senses: visual, auditory and kinaesthetic. Practical wet microbiology sessions inherently engage the kinaesthetic sense of movement and touch in hands-on activities, thus employing a kinaesthetic approach to learning. Action and activity are important for learning [13] and by engaging all three senses, the quality of learning is improved [14]. Practical experience also supports procedural memory by facilitating long-term memory of skills and procedures. In this context, quality learning is facilitated through relevant hands-on activities that are designed to provide students both choice and control of their learning process and also to foster interaction with peers for articulation and exchange of opinions and perspectives.

Recent research demonstrated that an inquiry-based approach enhanced student understanding in microbiology [15]. The laboratory context is one of the most appropriate ways in which to explore research-led teaching and can be used effectively to provide research experience to students, in which they investigate problems related to the design and execution of a scientific investigation and are challenged to develop skills in critical analysis, effective communication and group interaction [16]. Caccavo [17] suggested that utilisation of research-based principles and techniques to facilitate active learning in higher education microbiology supports lifelong self-learning and will propel student learning within the discipline. Furthermore, the incorporation of original laboratory-based research projects for senior microbiology students was shown by McLean [11] to motivate and prepare students to pursue careers in science. Research projects have been incorporated in the curriculum for advanced senior microbiology students at the University of Sydney for several years, fostering high order learning skills and stimulating progression to honours and higher degrees in the discipline.

Practical experience supports higher grades in undergraduate microbiology

Further evidence to support the significance of practical experience in microbiology comes through data from students enrolled in two introductory, intermediate units of study at the University of Sydney from 1998 to 2004. One unit contained both lecture and practical components, while the other was entirely lecture-based. The average number of students enrolled in the unit containing practical sessions was fourfold that of the theory-only unit, indicating, amongst other factors, that students recognised the importance of practical experience in supporting their learning in microbiology. Alternatively, students might opt to take the theory-only unit as a perceived easier alternative or if suffering from workload problems.

In analysing the results of students in the units by calculating mean values and comparing per unit per year, it was found that:

- Results of students in the lecture plus practical unit were significantly higher, by 10% on average, than results of students in the theory-only unit ($P<0.015$).
- The proportion of students with failing grades: absent fail, fail and conditional pass (no progression permitted) was significantly higher, by 33% on average in the theory-only cohort than in the lecture plus practical unit ($P<0.05$).

These findings were achieved despite the inverse finding that students taking the theory-only course entered the unit with previous academic performance significantly higher, by 9% on average, than students enrolled in the theory plus practical course ($P<0.004$), measured in individual AAMs (previous year's annual average mark). Although lack of motivation, laziness and workload issues could have contributed to poorer performance by theory-only students, clearly, practical experience in introductory

undergraduate microbiology at the University of Sydney provides students with better learning outcomes than students taking the theory-only unit and significantly supports progression in the discipline.

Student feedback recognises the value of practical classes

Finally, in a student evaluation survey for a senior unit, MICR3011 Microbes in Infection in 2007, when students were asked what things about the practical sessions helped their learning, written comments included:

> *hands-on activity … enhanced learning and allowed us to understand the concepts better*
>
> *gives what we learn relevance*
>
> *taking part and interacting was … beneficial*
>
> *provide real world applications of what we were learning in the lectures*
>
> *in conjunction with lecture material, reinforced learning.*

These students articulated how practical experience provided relevance and application, how their learning was enhanced through engagement and why deeper understanding was stimulated through reinforcement of theoretical principles. Support for these findings is found in the outcomes of a recent survey of Australian first-year nursing students [18]: that, of lecture, practical and tutorial deliveries, practical sessions were the most favoured strategy to benefit their learning with the preferred sensory mode being kinaesthetic, the hands-on approach to learning. **Furthermore, first-year students in the UK articulated social interaction as an important part of their learning experience and contributed to** "good practicals"[7].

In conclusion, this is compelling evidence that supports the inclusion of significant practical experience in undergraduate microbiology courses. Not only does the discipline have an inherently practical basis, but quality student learning outcomes result from experiential, engaged activities. Additionally, evidence is provided that students enrolled in an undergraduate introductory microbiology course, containing practical components, achieve significantly better results than students in the theory-only course. The potential exists through practical, research-led teaching to equip microbiology graduates with deep understanding and enthusiasm for the discipline by fostering assimilation, synthesis of ideas and critical thinking skills that are of real value in a dynamic, changing society.

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Biography

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