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Introducing Students to Ways of Thinking and Acting Like a Researcher: A Case Study of Research-led Education in the Sciences

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The concept of research-led education is gaining increasing attention in higher education. However, the concept may be interpreted in different ways, some more feasible within an undergraduate curriculum than others. The approach described in this paper aims to introduce students to ways of thinking and acting like a researcher through engaging in research-like activities during lectures, tutorials, practical sessions, and assessment. This case study models an approach to research-led education that involves identifying key research skills, then designing learning activities that encourage the development of those skills, such as collecting small amounts of data in laboratories, using data analysis, and writing weekly practical exercises and reports; presenting findings to peers; interpreting and writing results and conclusions to accompany data drawn from the research literature; exploring the literature in a research field and finding gaps in the research; and producing a mock research grant application. We conclude that this approach to research-led education can be integrated into the general undergraduate curriculum with relative ease**.**

There has been increasing discussion since the 1990's of the role of research in teaching. This seems to be in response to a number of forces acting on higher education, including increasing fiscal and workload pressures that have led to decreasing (and potentially competing) time and resources for teaching and research, government policies that are encouraging a separation between teaching and research (at least in Australia and the UK), rising quality assurance expectations, increasing concern with student learning outcomes, and greater competition among universities (leading research-intensive universities to emphasise a possible competitive edge). This concern with the role of research and teaching has been evident in the number of publications on the teaching-research nexus and also on the potential benefits of research-led education. It is this last body of research that we contribute to in this paper.

One thing that complicates discussions of research-led education is that different terms are being used in the literature and in practice to refer to the same idea, e.g., research-led, research-based, research-informed…. In addition, the same terms are being used to refer to different ideas—research-led education (and equivalent terms) are being used to refer to such disparate ideas as bringing research findings into the content of one's courses versus using educational research to inform the design of one's courses. While some authors use different terms to refer to these different ideas, there is no common consensus on terms, leaving the potential for much confusion as to what research-led education (or any related term) means.

Despite the variation in terms, there is more consensus on the range of possible meanings of research-led education. The most common distinction in potential meanings is drawn between:

> Pedagogical Research: i.e., using or engaging in educational research in order to inform the design of one's teaching and one's students' learning; and
>
> Disciplinary Research: i.e., using disciplinary research to inform the content of one's teaching and students' learning (Entwistle, 2002; Biggs, 2002; Brew, 2003; Holbrook & Devonshire, 2005).

Less commonly, further distinctions are drawn within the latter category, with disciplinary research viewed in terms of:

> Research Findings: i.e., introducing students to up-to-date research content and
>
> Research Practice: i.e., introducing students to ways of thinking and acting as a researcher (Francis, 2002; Brew, 2003; Durning & Jenkins, 2005; Holbrook and Devonshire, 2005.)

Ways of addressing research practice at the undergraduate level can include offering courses on research methodology, providing opportunities for students to conduct their own research projects (or to assist academic researchers in their projects), or the more innovative approach of introducing inquiry-based learning in undergraduate courses (Brew, 2003; Holbrook & Devonshire, 2005; Robertson & Bond**,** 2001; Robertson & Blackler, 2006; Trigwell, 2002). It is this last approach, introducing students to the practice of research through an inquiry-based course design, that is addressed in this paper.

This focus on research practice raises the issue of disciplinary differences in research processes. A number of authors emphasise the importance of acknowledging such differences (Durning & Jenkins, 2005; Entwistle, 2002; Holbrook & Devonshire, 2005; Robertson & Bond, 2001; Robertson & Blackler, 2006), leading to the value of having examples of research-led teaching in different disciplinary contexts. This paper contributes by presenting a case study of research-led teaching in the biosciences, highlighting the skills and thinking required of a researcher in the area and the ways in which these different skills may be emphasised in undergraduate course design. The context for this case study is a third-year undergraduate neuroscience course with an enrollment of approximately 50 students in a research-intensive university in Australia.

Although the case study is science-based, the model provided of identifying key research skills and designing lecture, tutorial, and assessment exercises to address these is relevant across disciplines.

Clarifying Key Research Skills

While the most authentic way of teaching research skills may be through guiding students in the conduct of their own mini-research projects (and this was included in the course to some extent), this is a more resource-intensive activity than most courses can afford. Consequently, the main approach to developing research skills in this course was through engaging students in research-like activities such as: collecting small amounts of data in laboratories, engaging in data analysis and writing weekly practical exercises and reports; interpreting and writing results and conclusions to accompany data drawn from the research literature; undertaking library research on an unknown topic, summarizing the findings and presenting it to peers; exploring the literature in a research field and finding gaps in the research in that field; and producing a mock research grant application.

Holbrook and Devonshire (2005), in their case study of research-led teaching in climate science, suggest that thinking like a research scientist involves the ‘routine’ activities of hypothesis, experimental design, experimentation, analysis, and scientific deduction. While we agree with this at a macro level, we thought it important to identify research skills in the biosciences at a more micro level. When students are inducted into research through conducting their own projects, multiple research skills are developed simultaneously. However, in order to develop students’ research skills through a series of small activities, it is necessary to isolate the kind of skills required for biological research so that learning activities and exercises can be better designed to address them.

The skills addressed in this course were:

- Observation: addressed through exercises where students were required to monitor changes in the structure or function of the central nervous system in response to experimental procedures.

- Description: addressed through inviting students to depict features or parts of the central nervous system based on histological images they were presented with.

- Analysis and interpretation of data: addressed through having students read scientific papers and explain the authors’ experimental results through graphs and pictures.

- Ability to discuss and brainstorm ideas: addressed through presenting students with a scientific hypothesis and having them talk about suggestions for experimental designs to prove or disprove it.

- Library research: addressed through giving students the task of researching the literature on a neurological disease.

- Presenting findings: addressed through asking students to describe their understanding of the neurological disease they had researched to their student peers in a seminar.

- Ability to apply theoretical knowledge in practice-addressed through asking students to explain the symptoms of disease based on the anatomical and physiological knowledge developed during the course.

The course curriculum was designed to contain learning activities that would encourage the development of each of these skills. These activities are described in detail in the next section.

Course Design to Develop Research Skills

In terms of contact hours, this course was given a standard university allocation of time for lectures and practical classes -- three 1-hour lectures and one 3-hour practical per week over the 13-week course. There was no time allocated specifically for tutorials within the timetabling, so to allow time for the small-group activities described below, two practical class times were used. Thus, the unusual emphasis placed in this course on students’ development of research skills was not dependent on special resources or circumstances. Nevertheless, the course coordinator decided to give up some of the lecture and practical classes to allow time for group project work, as will be described below.

Library-based Research Project

Laboratory-based projects may be the ideal approach to developing research skills, but they are also unrealistically resource intensive and unessential to the development of many research skills. To learn some of the most important skills, for example, the skills of understanding the literature in an area of research, and presenting and planning further research, students were asked to undertake a library-based research project in small groups. While it is not unusual for courses to involve library research, what made this project innovative was its complex, multi-faceted nature and the focus on applied relevance. The project involved literature searches, a group presentation on findings, and group preparation of a grant project proposal for future research in the area.

Given the complexity of the project, students were given four weeks to complete this task. During this time, two tutorials were conducted (described further below), one to manage the logistical aspects of getting the project under way, and one to help students develop the research skills needed for the project. Further, two practical classes were set aside for students to conduct their research and engage in group discussions, as well as to prepare for their presentations. The number of lectures was also cut back during this time so that the last two weeks of the project preparation time was free from all classes -- lectures, tutorials and practical classes.

The library research project was divided into three stages: a literature search, a seminar presentation and a research grant proposal.

Literature search. In this task, students were required to research existing literature on a given topic. They were given a list of neurological and neuro-ophthalmic diseases and asked to submit a 'wish list' of their preferred three topics. The course coordinator then assigned students to small groups (of 4-5) based on their preferred topics, and they were given the task of thoroughly exploring existing literature on the topic, including present understanding of the disease patho-mechanism, its symptoms, and their anatomical and physiological interpretation as well as treatment approaches to date. Students also needed to explore the present state of basic science research into the disease. This led to three core library research tasks: a critical assessment of the basic science research literature; a description of the disease mechanisms, symptoms and interpretations; and an explanation of current approaches to therapeutic interventions.

The project involved a mixture of group and individual work. The student groups had the responsibility of dividing the three different aspects of the literature research among themselves, and they were to work on their tasks individually. Student groups met for the first time at the beginning of the first tutorial session, when the group compositions were announced. Students had 30 minutes to agree on a future meeting time, where they were to divide tasks. The coordinator gave a deadline for the groups to have their first meeting, and they were instructed to report on the task divisions to the coordinator by email. Students were encouraged to contact the coordinator or tutors with any problems or questions. The suggested time for this part of the project was four weeks. Group presentations had to be submitted to the course coordinator on disk at the end of the allocated time for preparation to ensure that all students had equal preparation time irrespective of when their presentation was scheduled.

Seminar presentation. Following the literature research, the students then summarised their findings as a group and presented them to an audience comprised of academics and their peers. Each group had an allocated time (1 hour) to present their topic and answer questions. Given the number of groups (about 10), all lecture and practical classes were given over to group presentations for two weeks.

Individual members prepared and presented their findings on the section they were responsible for, allowing for presentation marks to be allocated to individuals. Members had to work out the content of their presentation and discuss it with the rest of the group in order to avoid overlaps. (Some groups even requested a practice presentation to make sure the presentation flowed well.)

Individual students were given marks by the audience, both academics and student peers, based on the content and quality of their presentation. All students were marked by all academics present (the course coordinator and four tutors), while four randomly chosen students were also asked to mark presentations, as it is important for scientists to be able to reach an audience with different levels of knowledge. However, academics and peers were asked to mark different aspects of the presentation based on their relative expertise in the subject area.

Research grant proposal. The last task in this project involved full group work, where the members had to come up with a gap in the research into their chosen disease and submit a group project proposal for future research, following an existing granting body's application form. The submission had to include the aim and rationale of the proposed research, the methods to be used, a timeline and a budget. Students were encouraged to let their imagination run freely and to incorporate advanced methods used in the field of neuroscience. The suggested time for this part of the project was two weeks. Groups were working on this aspect of the project during the time when presentations were ongoing.

Tutorials

Two 3-hour tutorials were timetabled during the course, one to enable the formation of groups for the library-based research project and give guidelines on the tasks ahead, and the other to help students analyze and understand scientific literature and express ideas on new scientific theories, as preparation both for their project and the final exam. This tutorial was timetabled towards the end of the course so that students could use the theoretical knowledge they had gained during the course. It was explicitly designed to develop research skills through the use of three different tasks: analysis and diagnosis of a neurological case; completion of the results and discussion sections of a scientific paper; and design of experiments to solve a scientific problem. The tutorial was conducted in two repeat sessions to permit a smaller class size. This allowed the tutors to observe student participation and encourage the more quiet students to participate in the discussions. It is easier to get students participating in a more relaxed environment, so cookies and lollipops were also provided to achieve an informal setting. Students worked in small groups to encourage peer discussion. Each group engaged in three types of activities.

Neurological case history. A neurological case history was presented to students on paper, and students were given around 30 minutes to analyse the symptoms, consult resources available (books, lecture notes), discuss these within their group, and suggest a group 'diagnosis'. After the given time, an all-class discussion was held where students presented their diagnosis and an explanation of how they had reached their conclusion. This provided a good opportunity for students and tutors alike to find and clarify misconceptions in neuro-anatomy. It also helped students to see the practical relevance of the knowledge they had gained in this field.

Completing a scientific paper. To practice the skills of observation, data analysis and interpretation, students were presented with part of a scientific paper. The introduction and methods sections were available in full; the results section was, however, limited to the graphs and images without any text. Students were given 40-50 minutes to analyse the results in small groups, draw conclusions from them, and write them on butcher's paper for the whole class to see. Finally, they needed to state whether they thought that the authors had answered the scientific question/s they had set at the beginning of their paper. After the given time, discussion was opened up to the class as a whole, and groups took turns in explaining their analysis of the graphs and figures in the article and justifying their conclusions.

Brainstorming experimental design. Peer discussions of scientific ideas are a major part of research. In the third tutorial task, the students were presented with a scientific question or theory (e.g., the question of how to go about testing colour discrimination in bees, or the theory that high tissue oxygen plays a role in the late stages of retinal degeneration). Students were then asked to brainstorm within their small group what experiments they would propose to prove or dismiss this theory. After around 40 minutes of small group discussion, ideas were discussed in the class as a whole.

Practical Classes

Weekly 3-hour practical sessions were held throughout the first half of the course. These were designed to develop students' skills in data collection, observation and understanding the relevance of theoretical knowledge in practice. (Later practical classes were replaced by tutorials, group project time and student presentations on the project, as described earlier.) The practicals took different forms in different weeks. There were three computer-based and three laboratory-based sessions. All practical classes required students to follow instructions and answer questions in their laboratory notes. This notebook formed the basis of their weekly practical reports. Students were presented with different types of exercises, for example:

Histological images. In one type of exercise, students were presented with images of histological preparations of the brain, retina or glia on the course's web page. These images reflected current research in the area, having been produced in the laboratories of some of the department's lecturers. In their practical notebooks, students were given a short explanation of the images and asked to respond to questions or perform tasks, such as describing the histology of a sample, to drawing sketches of certain cell types, or explaining the results and drawing conclusions from them.

Small experiments. In another practical, students conducted a small experiment by themselves. This activity involved the histological staining of prepared tissue samples, followed by cover slipping and microscopic examination of the sample. Students were asked to draw a sketch of the tissue, describe the microscopic picture, and identify the tissue based on the knowledge they had gained during the previous week of lectures and practicals.

Computer simulations. In another activity, students used a computer program that simulated the physiology of neurons. This required students to 'conduct' voltage- or current-clamp experiments, collect data, present them in graph format, and explain their results. To help them in preparing their results, they were guided by specific questions in their practical book. Students were required to summarise data in tables and graphs, describe results by explaining the data in writing, and analyse findings by discussing their significance.

Lectures

In general, three one-hour lectures were held each week. The lectures aimed to provide appropriate building blocks for the neuroscience course, addressing anatomical structures, membrane properties, the process of eliciting an action potential, the roles of membrane channels, etc. in a largely preset curriculum. However, this didn't mean that the development of students' research skills needed to be neglected.

Lecture quizzes. When a new concept was introduced and explained during a lecture, a relevant image and question for the students to answer would be presented on a slide. This was designed to show students the relevance of the new concept. For example, after teaching the anatomy of the circulatory system of the brain, an angiographic picture of an aneurysm was shown to the students and the question was, "What consequences would the rupture of that aneurysm have in a patient?" The students could discuss the location of the aneurysm, the vessel involved, and the surrounding anatomical structures. From there, the implications for loss of certain functions (e.g., sensory or motor system symptoms) were discussed.

Students were allowed up to five minutes for open discussion and to suggest answers to the lecturer. Once the right answer was given, that student was asked to give an explanation to the class as a whole as to how he/she reached his/her conclusion. At this point, students were encouraged to ask questions to make sure that they understood the answer. This exercise was aimed to develop skills such as observation, description, understanding and interpreting data/findings, logical thinking, presenting ideas and applying theoretical knowledge in practice.

As an added benefit, during the open discussion, the lecturer was also able to assess the percentage of students with a good understanding of the concept. If the lecturer wasn't satisfied with the level of comprehension across the class as a whole, she would spend more time on the relevant concept, explaining it further and encouraging students to ask questions to clarify their understanding. Following the open discussion, students seemed to be more ready to be interactive and ask questions during the follow-up session.

Expert guests. Students also listened to formal lectures given by experts in the field of neuroscience. These lectures aimed to teach key concepts in the area as well as to demonstrate the present state of research in the field, including the latest developments and the work conducted in the guest lecturer's own laboratory. While this aspect of research-led education, 'teaching what we research,' is common, it has its limitations. Although students can hear about the latest advances in the field, it provides little opportunity for them to develop their research skills, which is why the course coordinator used lecture quizzes in her own lectures.

Optional Lab Project

Given the size of the class, it was not possible to offer laboratory-based projects as an integral part of the course. Difficulties in recruiting willing academics with suitable hands-on research activities to offer students, as well as making sure that the level of student involvement in such projects was equal or at least similar in all participating laboratories, makes the integration of this type of activity in an undergraduate course difficult. Nevertheless, rather than not provide this opportunity at all, students in the course were given the option of undertaking a 'mini-project' in the laboratories of the course coordinator on a voluntary basis.

During an informal meeting, the activities of the laboratories and the type of possible projects were described. Interested students (some 5-6) were asked to approach the coordinator for an individual discussion about their goals, plans, interests, possible time commitments, and any special requests (e.g., allergies). The course coordinator had a list of short experiments on offer. Based on the discussion with interested students, an individual project and experimental plan was outlined.

Students then were asked to start a literature search and produce a review paragraph to demonstrate their understanding of the background for their individual project. A timeline for the project was also determined at an early stage. Students were coached in techniques they needed in order to conduct their project. Discussions between the student and coordinator occurred regularly, as required. Students were guided through the entire process of data collection, analysis and description of findings.

Although this activity was highly time consuming for the course coordinator, it did provide the opportunity for students interested in research to gain valuable research skills, as well as to ascertain if this is really the career or field they wish to pursue. Students had the option of submitting a report on their project, complete with background, methods, result and discussion sections. These reports were assessed and worked into their course work mark, typically by counting as a 6th practical report (see the following section on assessment).

Integrating Assessment into the Course Design

The assessment for this course was designed to support the course focus on development of research skills. It consisted of:

- Five practical reports, worth 25% of students' final grade (i.e., 5% each);
- Student presentations, worth 20% of the final grade;
- Group project proposals, worth 5%; and an
- End-of-semester exam, worth 50% of the final grade.

Practical Reports

The practical reports were designed to help students' learning by giving them tasks that would help clarify the basic research or clinical relevance of the topics or concepts addressed in lectures during the preceding week. They required students to use their theoretical knowledge in practice. The reports also aimed to develop students' research skills by presenting them with exercises where the skills of observation, analysis and presentation of findings needed to be utilized.

The type of exercises required for the reports, described in more detail in the preceding section of the paper, included the summary of data collected during the computer-based experiments or in vivo (e.g., measuring reflex time on each other), or a description and analysis of images presented during the practical. Students were expected to complete some of the reports during the practical session, while others were to be completed at home using additional resources. Only five of the reports had to be handed in for assessment. However, many students submitted all six reports for feedback, and in those cases, the five best marks were counted towards their course mark. Each of these reports contributed 5% towards students' final mark. So, this part of the course gave a total weighting of 25% towards students' overall course grade.

Student Presentations

It is a very important skill for a scientist to be able to communicate his/her findings and thoughts to their peers and the general public. Therefore, there was an emphasis in the course on student presentation skills. As described earlier, students had to prepare an oral presentation on their chosen library research topic. Marks were given based on the content of their presentation, such as relevance, logical flow and proper referencing, as well as their presentation skills, such as the quality of their slides and the manner of delivery. The presentations were marked by four randomly selected peers (making sure that they were not peers from their own group) as well as by the course coordinator and tutors. An assessment sheet was prepared by the course coordinator which contained the categories the marker was asked to concentrate and comment on, and the weighting for the different aspects of marking were indicated. Different assessment sheets were prepared for academics and peers to cater to their different levels of expertise in the area. The marks were then averaged, contributing 20% towards students' overall course grade.

Project Proposals

Many young scientists find writing grant proposals very hard. However, it is a way of life in the academic environment, and it is commonly the only way to get resources for our research. In the present economic environment, where universities offer fewer and fewer continuing positions, scientists have to rely on external funding not only to conduct research but also to have salaries for themselves. Thus, learning to write good project proposals is paramount. As such, the course coordinator felt that it was important to have an activity to introduce students to this vital part of scientific life.

Since the proposal was part of students' course project, they had a good understanding of the literature of their chosen topic by the time they were preparing their proposal. They were encouraged to use their imagination freely; they could use any aspects of their theoretical knowledge gained in other courses during their undergraduate studies, e.g., many suggested experiments involving molecular or biochemical techniques. The ability to integrate their knowledge is invaluable for understanding the practical relevance of the knowledge gained during their time at the university. It also demonstrated their skills in translating theoretical knowledge into practice. The formatting of their writing and the creating of a timeline for the project required different skills, the presentation of ideas and time organisation. The preparation of a budget made students aware of the expenses involved in scientific research.

The group project proposal contributed 5% to the overall mark. The weighting placed on this task was seemingly low because this was the first year this exercise had been given, and the novelty of the exercise warranted a lower weighting. However, it proved to be a popular task amongst students, and the course coordinator was happy with the quality of project proposals produced by students. In the future it can have a more prominent place in the assessment scheme.

Final Exam

The final examination tasks were formulated to test student understanding of the subject and the research skills they had gained during the course. They included a mixture of traditional and more innovative assessment tasks. There were three types of tasks: short answer, case history and essay.

Short answer questions. To assess the students' skills in analysing and understanding data, short answer questions were used. Students were presented with graphs or images based on real data taken from the lecturers' own research results. A short explanation was given with the data, and students were asked to answer questions related to the graph/image. For example, students were presented with a picture of part of a normal and a diseased brain. The accompanying task was to describe two major differences between the two samples and to state the relevance of the changes in the diseased sample, with the possible clinical consequences. In another question, students were presented with a series of patch clamp recordings and were asked to plot the current-voltage relationship and explain, based on the result, which ion(s) they expected to permeate the examined channel. This exercise involved the same skills as one of the tasks they had been given during the tutorial session, where they were asked to interpret the results of a scientific journal article. It showed their ability not only to analyse and understand data but also to present their findings

Neurological case. To test their anatomical knowledge and their ability to apply that knowledge in practice, students were given a neurological case and asked to explain the disease symptoms in anatomical and physiological terms. They were encouraged to use sketches to explain the anatomical structures involved in the disease and, finally, to give a 'diagnosis' as to the location and type of lesion (e.g., tumor, haemorrhage, degeneration). This exercise involved the same skills as the neurological case analysis conducted during their tutorial session.

Essay. Students were also presented with a number of topics covering the whole course material and were asked to write a traditional essay on their chosen topic. This task was chosen to be part of the examination to provide students with a more familiar type of assessment, and thereby to relax them before they were faced with the more challenging part of the exam paper.

Success of the Course Design

Conclusive evidence of the success of the course design is difficult to establish. However, one indicator comes from student evaluations of the course. Student evaluation surveys are routinely conducted for all courses in the school. Although the survey form was not tailored for the innovations in this course, ratings of the course coordinator's effectiveness as a lecturer were collected. These averaged 4.56 (out of a maximum of 5), compared to an average of 3.91 across the school as a whole, and 4.00 for the same course coordinator in the previous year.

A more objective assessment of success comes from gains in students' learning, as measured by students' ability to tackle problems during the course in their assignments and at the end of the course in the exam. Since the exam questions were designed to present problems or tasks similar to the ones in the assignments, it allowed us to see the improvement of students' ability to respond to such questions over the duration of the course.

As Nikolova Eddins and Williams (1997) stated, there is an increasing need for students to be more prepared for their future careers by bringing classroom experiences and career skills closer. Well-developed skills empower students for their future by letting them enter into the workforce (including academia) with confidence and ease. Although the students found the structure of this course extremely challenging, we noticed that the assessment results gave a good representation of the students' scientific abilities. Further, the course helped students to utilize their own thinking skills, rather than just attending the lectures and submitting assessments without necessarily thinking any further about the relevance of their studies. Many students from this course chose to continue on the path of research and enrolled into the university's neuroscience honors program.

Costs and Benefits of the Course Design

With the increased interest in research-led education, institutions are under pressure to increase laboratory space and equipment to allow students the experience of more research-like learning, and academics are under pressure to accommodate students in their labs. Given a simultaneous pressure to increase student numbers, the task of research-led education would soon become impossible if it were interpreted primarily as providing students with lab-based research experience. In this paper we illustrate a more affordable approach to research-led education, providing experience in research skills through a course-based approach.

We have found this to be a manageable approach to teaching ways of thinking and acting like a research scientist to undergraduate students. Nevertheless, there are still costs in both time and material resources to be accounted for. For the laboratory-based projects and activities, materials already available in the course coordinator's laboratories were used. A modest overproduction of slides during postgraduate and honors students' projects or other personnel's work, for instance, can be utilized to provide students with individual slides for staining. The images used in the online histology assignments were also obtained from the course coordinator's and her colleagues' research material. Whilst the initial preparation of such online material takes weeks, it is largely a one-off exercise, so it is well worth the effort as the material can be re-used over time. In the computer simulation activities, we used a freely downloadable teaching software (Neuron), which comes with pre-designed activities that allow a relatively quick set up. Nevertheless, there is a time commitment involved in tutors and demonstrators familiarizing themselves with the program.

Other activities required the purchase of some hardware or accessories. Dissection activities needed the purchase of specimens, usually for a moderate price. Physiological experiments utilized commercially available hardware (PowerLab, AD Instruments Pty. Ltd., Australia). The basic hardware set-up is usually costly, depending on the number of units needed; however, the data acquisition system can be shared between several courses and programs within the university. In our case, the institution already owned and used the system in two other programs, and we only had to make a one-off purchase of accessories relevant to our course, which did not pose a high financial burden. It is also possible to utilize institutional workshops to create such accessories, as happened in our case a few times.

In summary, by looking at one's own research and thinking of ways to use existing materials, techniques, or the literature in teaching undergraduate students, the costs of developing a course or modules similar to the ones described in this paper may be minimized.

Benefits to the students have already been outlined. For the teacher, the change in thinking for linking research and undergraduate teaching proved to be challenging but also enjoyable. To watch the intellectual growth of students gives enormous satisfaction. To witness the evolution of a thinking, inquiring young scientist during the course of the semester is what we all try to achieve. It was evident that, with time, students became more relaxed and confident in their knowledge and, based on the exam results, many achieved a deep understanding of the practice of neuroscience.

Conclusion

The authors' home institution's Education Management Plan clearly states that its education should take strength from the research-intensiveness of the institution. The stated objectives of education, amongst others, are 'to challenge and extend students, guide them in self-directed learning and, through discovery-based education, prepare reflective, analytical and questioning graduates.' However, when it comes down to strategies for achieving these objectives, the Management Plan offers only general guidelines on how to integrate research into the curriculum -- mainly through the increased use of high quality researchers in teaching. The development of undergraduate and postgraduate coursework programs with a significant component of genuine research is also encouraged.

Unfortunately, research-led education along these lines can only be offered to very able undergraduates and to postgraduates, since 'genuine' research is costly. If research-led education is to be available to all undergraduates, less costly approaches are needed. This paper presents an example of how discovery-based and research-led education can be introduced into the mainstream curriculum in an affordable way. By identifying the key skills researchers in a discipline need, students can be introduced to these skills and related practices from an early point in their undergraduate studies without a major increase in expenses.

The present study gives numerous examples of introducing students to research practices within a course work setting. Although this case study is based in the natural sciences, the same approach to teaching research skills could easily translate into other disciplines. For instance, the idea of library-based group research projects culminating in preparing a mock research grant proposal is applicable to any discipline. Not all disciplines have practical classes, but tutorials are common, and designing tutorials to include analysis of case studies and completion of partial research papers would again be possible in any discipline. The use of problem solving tasks or projects to develop critical thinking and analytical skills is also relevant to a wide range of disciplines. Some of these strategies require more effort from the course convener than others. However, the benefits for students, teachers, and institutions outweigh the initial time and energy required to introduce such activities.

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