

# PAUL MACPHERSON TEACHING FELLOW APPLICATION

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**Engaging undergraduate students in authentic research: Creating a new paradigm for teaching and mentoring students in the lab.**

## PROJECT PROPOSAL

### ABSTRACT

It is widely accepted that the undergraduate experience can be greatly enhanced by engaging students in research opportunities (Kloser *et al*, 2011). These opportunities may be broadly classified into course-based labs, inquiry- or project-based labs, and authentic research experiences. Authentic research experiences are those in which students are working directly in a research lab and contributing to novel research and discovery. Undergraduate Research Opportunities (UROPs), in which students are engaged in authentic research, are regarded as the most effective way of encouraging students to stay in and succeed in careers in science, technology, engineering, and mathematics (STEM; Seymour *et al*, 2004; Russell *et al*, 2007; Kloser *et al*, 2011). With increasing numbers of undergraduate students, most students will be enrolled in a few course-based labs while students in elite programs are engaged in inquiry-based projects. Space, resources, and importantly time, limit student access to an authentic experience in a research lab. With growing student populations and limited resources, the proportion of students who may participate in authentic lab experiences is decreasing. In addition, the experience, when available, is restricted to the fourth year. This means that a vital complement of skills and attitudes essential to modern science – critical yet creative thinking, experimental design, data interpretation, even career planning – are only experienced (if at all) toward the end of a student's undergraduate studies. The majority of our students will not have this opportunity.

The aim of this proposal is to ensure that the skills and methods just described are central to a scientific education, not just in the final year of study and not to a limited number of students in elite programs, but from the very outset of every student experience at McMaster.

Traditionally, one or two students will join a lab in their fourth year for a thesis project and work with an assigned mentor, a graduate student or a postdoctoral fellow. This proposal explores the possibility that research labs can instead supervise more undergraduate students, in parallel, on common projects. Instead of a single student engaged in a UROP, multiple students would be engaged in a Collaborative Undergraduate Research Opportunity (CUROP). The primary goal of my proposal is to provide research faculty with a viable model for this more inclusive and effective approach to undergraduate education in the sciences.

The proposal is aimed at developing tools that researchers can use to engage multiple undergraduate students early and often in original, publishable research. The essential tool is an electronic lab manual or iBook lab manual that can walk young researchers through some of the basics of lab research. This manual would not replace the value of a mentor in the lab, but would ease the workload on the mentor and facilitate bringing more undergraduates into the authentic lab experience.

### PROJECT OBJECTIVES

- The primary objective is to provide research faculty with tools that will allow them to bring more undergraduate research students into their lab. This would provide more students with the valuable opportunity to engage in authentic research, an experience that will enhance their entire university program. These Collaborative Undergraduate Research Opportunities are called CUROPs.

## STEPS TO REACHING THE PRIMARY OBJECTIVE

- Publish iBook titled Nematode Diversity Project: Undergraduate Discovery Project Manual. This would be a free, open-access lab manual available to the general scientific community.
- Posting lab manual or link to the free iBook on McMaster websites and on WormBase (an online forum for nematode research) for use by other research faculty at McMaster University and beyond.
- Create generalizable scaffold of iBook that can be applied to diverse research projects and teaching/training applications.
- Create 'bookends' that can be included in the iBook scaffold that include lab safety, lab etiquette, maintaining a lab-notebook, question-based literature searches, poster presentations, and writing a scientific report.
- Create modules for a variety of common lab techniques that could be slotted in and out of the iBook for different research projects. These would include "Running RT-PCR", "Performing a Western Blot", "Immunohistochemical labeling" and would contain short videos that review the procedures. Topics would be determined by conversations with participating research faculty. These modules and video components would be created by paid student researchers and students engaged in placement courses.
- Completion of a lab manual development guide that would enable other adopters to develop the CUROPs using the iBook manual.
- Meetings with interested labs to initiate and support the development of a personalized iBook manual that would be used by students in CUROP projects in the lab.
- Presentation of the project at both Education Technology conferences (Learning Technologies Symposium, McMaster University) and Teaching and Learning conferences (STLHE conference).
- Measuring outcomes on student engagement; evaluation of the initial impact of the iBook lab manual and the CUROPs on student learning and student engagement.
- Measuring outcomes on faculty attitudes; evaluation of the research faculty's perception of the quality of the student research and the students' lab skills.
- Undergraduate research assistants will be employed in each of the above steps from creation of the interchangeable iBook modules and creation of animation and graphics (in association with the Biology Illustration Suite) to analysis of the pedagogical research questions.
- Organizing a lecture series in 2015/16 titled "Engaging undergraduate students in authentic research" with invited speakers from other Universities who have projects similar to CUROPs in their research labs.
- Establishing a fund for CUROP projects so that Undergraduates can formulate research ideas, apply for funding with a research proposal, and realize their idea.

## BACKGROUND & RATIONALE

Scientists at research-focused universities are asked to balance a competitive and stressful research agenda with their contribution to the education of a growing undergraduate student population. While research faculty do enjoy and benefit from having undergraduates in the lab, it is difficult to provide an enriching experience for a large number of students. Scholars have the responsibility of pushing the boundaries, discovering the unknown, but also of sharing their excitement for the process of discovery with students who may become scientists or who may go on to inform science policy as decision makers and voters. Our counterparts in the United States have emphasized that undergraduate education could be improved by a higher level of student participation in authentic research. This is exemplified by the Howard Hughes Medical Institute's HHMI professors program in which 55 research faculty have developed projects to engage undergraduates in the research experience (<http://www.hhmi.org/programs/hhmi-professors>).

This proposal builds upon the idea that engaging undergraduates in authentic research early and often is beneficial to the students (Seymour *et al.*, 2004; Russell *et al.*, 2007; Kloser *et al.*, 2011 and to the research labs (Kloser *et al.*, 2011). A well-designed and user-friendly plan can benefit both. We have had success with this approach in some of our own, small-enrolment, elite programs. In the integrated Science or iSci program here at McMaster University, approximately 40 students per year are engaged in research from level 1 through 4. Early

evidence from the first graduating year suggests that this approach encourages many iSci students to stay in research at the graduate level. Similarly, if we look across programs in Biology, Biochemistry, and Life Sciences, the decision to go into graduate research is dependent upon the experience of an independent research project. Often this decision comes in their fourth year despite prior experience in course-based research.

Are there ways in which we can push the envelope further and provide tools and resources to encourage researchers to bring additional students into the lab at different stages in their program? By engaging students in Collaborative Undergraduate Research Opportunities (CUROPs) and facilitating the student training using iBook lab manuals, I believe the answer is, yes.

Previous funding from MIIETL (Teaching and Learning Grant, CLL, 2010) and the Academic Science Fund (ASF, 2012) provided the means to establish the Nematode Diversity Project and then the fundamentals of the Nematode Laboratory iBook (electronic book), respectively. The MacPherson Fellowship would allow for the publication of the Nematode Diversity Project iBook Lab Manual and for the publication of a research outcomes of the effectiveness of the CUROPs. Most importantly, the fellowship will allow me to take the Laboratory iBook structure to the next level such that it can be modified and used by other labs at McMaster University and beyond. Ultimately this will allow McMaster University to engage many more undergraduate students in authentic research. Simply put, the tools developed from this project will allow many diverse lab research projects for one undergraduate student to be amplified to involve multiple students.

At McMaster University, we have a large student body in the Faculty of Science, many of whom are not able to participate in novel research at any phase in their program. This is disappointing given the documented benefits. What are some of the impediments to bringing more undergraduate students into the lab? Researchers are faced with a limited space, resources, and time for supervision of these students. Although there are advantages to having students in the lab during consecutive years, faculty researchers are reluctant to bring in first and second year students as they require extra training and supervision. Addressing these issues will require more than one solution. This proposal addresses some of the problems and provides direction on how to approach the other impediments.

There are many additional advantages to the iBook lab manual for specific students. There are some students who may otherwise not choose to complete undergraduate research. The iBook lab manual may allow greater access to an authentic laboratory experience for students registered with Student Accessibility Services (SAS). Students with learning disabilities will benefit from the opportunity to review techniques and protocols and to watch the techniques being performed in videos. Students with increased anxiety will gain confidence from reviewing techniques and the checkpoint questions. Advisors may be more willing to take on students earlier, in their 3<sup>rd</sup>, 2<sup>nd</sup> or perhaps 1<sup>st</sup> year, if training occurred before the student comes to the lab.

In one study of undergraduate students completing thesis projects, students reported that they perceived scientists as isolated, working alone, and unaffected by scientific institutions (Ryder, 1999). This may be in part because students think that they must figure things out on their own and that they should not disturb the graduate student or the postdoctoral fellow with whom they are working. This iBook lab manual would give students more confidence to proceed with less input from graduate students and postdocs. Importantly the CUROPs would allow students to interact and collaborate with one another, which is a realistic representation of how research in the lab typically proceeds and provides a supportive and positive environment for the students.

## **PROJECT DESCRIPTION**

### **CONCRETE DELIVERABLES**

The deliverables resulting from this project will fall into four categories:

- 1) Direct products from the Nematode Diversity Project. These would include the Nematode Diversity Project iBook lab manual and associated pedagogical research publications based on student evaluations and assessments.
- 2) Transferable products that include the creation of the iBook manual scaffold, associated 'bookends', laboratory skills modules, and the iBook lab manual development guide.

- 3) A workshop that aims to excite researchers about CUROPs and inform them about the use of the iBook manual. Interested faculty would be encouraged to arrange a meeting with me to introduce the idea of the iBook and discuss the individual needs of each project.
- 4) Two invited speakers in 2015/16 under the title “Engaging undergraduate students in authentic research”.
- 5) Analysis of the impact of the project on student engagement and learning and on the perceptions that research faculty have of the value of the iBook lab manual and the CUROP projects.

#### SPECIFIC ASPECTS OF THE PROJECT

##### *Nematode Diversity Project iBook lab manual:*

An iBook is a form of electronic book that can be opened on an Apple iPad. Parallel formats include ebooks that can be read on eReaders. The Nematode Diversity Project iBook lab manual is an iBook that acts as a lab manual. The advantages of an electronic form of a lab manual over the traditional paper copy, or even a static pdf, are many. The Nematode Diversity Project iBook lab manual describes the protocols to be used and employs video demonstrations of the techniques. A student’s understanding of the principles behind the techniques is tested using embedded questions. When a student chooses a wrong answer, he/she is led through an explanation of how to get the right answer. Questions take the form of videos in which students watch a person step through a protocol that leads to a failed experiment. Students are asked to review the video and see where the person went wrong. Trouble-shooting in this fashion prepares the students before they get to the lab. This may save valuable time and resources in the lab.

The iBook will not replace the mentorship that comes in the lab through direct interaction with the researchers in the lab. Instead the iBook provides the means for students to learn some of the concepts, skills, and techniques first in the iBook and then to practice and master the technique in the lab. ‘Bookends’ are chapters at points in the book that are not specific to the research topic, but that are necessary for participating in lab research. Topics include safety protocols (which are in conjunction with, not instead of, McMaster University training), literature research, lab etiquette, presenting at lab meetings, presenting a poster, writing a paper, and writing undergraduate research proposals. These are all components that may be appropriate to a lab experience in any department. There is some evidence for the usefulness of having common training for basic research techniques that can enhance the undergraduate research experience. Reynolds et al (2009) have shown that taking a systematic approach to teaching student writing to all thesis students, rather than leaving it solely to the supervisor, can increase student confidence and the quality of the final product.

As of Winter 2015, there are few examples of student lab manuals published in iBook or other electronic formats. Almost all of these examples are printed books that have been alternately published as eBooks, but do not take advantage of the opportunities to embed demonstration videos, interactive elements, and quizzes into the book. One example that stands out is *Understanding Anesthesia: A Learner's Guide* by Dr. Karen Raymer. Dr. Raymer is a Clinical Professor, in the Department of Anesthesia (Faculty of Health Sciences) at McMaster University. This is one of the first examples of a truly interactive lab manual. The target audience is medical students specializing in anaesthesiology. The only other example that is in the public domain is a medical microbiology lab manual from the University of California, Irvine. Although the Nematode Diversity Project iBook lab manual is being developed as an iBook, the proposal aims to publish this in an alternate format that could be read on non-Apple devices and could be opened on a PC or MacIntosh computer.

##### *CUROPs:*

The idea of Collaborative Undergraduate Research Opportunity (CUROP) is not new. There are examples of researchers that routinely bring numerous undergraduates into their labs to perform parallel experiments. Examples include having undergraduate students screen through a collection of mutations for specific phenotypes or effects; screening through samples exposed to different chemicals for unique effects; field sampling and analyzing samples for specific characteristics in the lab. This project aims to make it easier for labs to take on many more students by giving students the skills to learn techniques first in the iBook and then to practice and master the technique in the lab. By reviewing the technique before performing it, the student has increased confidence and is more likely to do the task well. This would save time and resources for the lab.

Part of the fellowship time would be spent on “selling” the idea of the CUROPs to other research labs. By demonstrating the value of the iBook in student learning, I believe that more labs will be willing to take on multiple undergraduate students. By showing that students in the CUROPs are capable of producing high-quality, publishable research, more researchers will be interested in bringing students into their labs. In the Department of Biology, a laboratory space has been created that is primarily for undergraduate research projects. This is a student-centered environment that is designated not for lab coursework, but for independent student research. Researchers can mentor student projects in this space as part of annual undergraduate projects in collaboration with Teaching Professors in the department. This will serve as a model for undergraduate research space in other departments in the Faculty of Science.

I also suggest that part of the money be used to seed a fund to which students and their faculty mentors may apply to resource their projects. A call for proposals would go out to students with creative ideas that they want to explore and to faculty members who wish to encourage more undergraduate research opportunities. One example may be a group of students with a novel research idea in need of a mentor, space, and a few hundred dollars for resources. Students from across the Faculty of Science would be able to apply for these funds. While some of these may be wet-lab projects, a review committee would be open to ideas on field research, pedagogical research, or other approaches.

#### *iBook Lab Manual Development guide:*

To make it more appealing to researchers to create and adopt the iBook lab manual for undergraduate student training, I will develop a written manual – the iBook Lab Manual Development guide. This will clearly explain the available bookends and when and why they would be useful. It will explain how to develop the topic specific chapters in the provided scaffold. It will provide guidance on developing questions that check student understanding of concepts and techniques. This development manual would be available in conjunction with in-person discussions about project development

#### *Working with faculty:*

I will dedicate some of the fellowship time to helping other labs develop their own iBook lab manual. This will involve working with one or more individuals in the lab to take a look at the specific needs of the new research project. I supervised an experiential placement student in the initial stages of development of the Nematode Diversity Project iBook lab manual. This student was enrolled in a Science 3EP3 course in Winter 2012. She wrote out protocols and took photographs of equipment and procedures as part of the first word document draft of the lab manual. Currently, there are multiple Department-specific placement courses in which students can volunteer to work on a project on or off campus. I recommend that a lab interested in developing an iBook lab manual adopt a placement student to work directly with me and a researcher in the lab to assemble a first draft of the iBook lab manual. We would decide upon which available bookends should be used and think about how to adapt the relevant lab protocols into the electronic format.

In addition, I wish to hire undergraduate research assistants in each term of the Fellowship to work on recording videos of lab techniques for research-specific modules, creating animations that explain techniques, developing embedded quiz material, and working with our collaborators in the research labs to create their own version of the iBook manual.

My dedication to the development of new iBook manuals each year would continue. Each project would require a placement student and a dedicated lab member. I would be limited to one project per term. I would be interested in projects from any field of research from physics and chemistry to biochemistry and psychology.

#### *Lecture series in 2015/16 on “Engaging undergraduate students in authentic research”:*

If one goal of this project is to develop the tools to enable research faculty to easily engage more students in authentic research, the necessary partner goal is to convince research faculty that this is a worthwhile endeavor. I seek to do this by example and communication. There are several examples of researchers at Universities in the United States who have successfully brought groups of students into the research lab and produced interesting and publishable data. Two researchers, one per term, would be invited to McMaster

University to give a seminar on their approach to science teaching and their experiences. In this way I hope to inspire research faculty to begin engaging in supervising CUROPs.

#### WHEN AND HOW DO YOU PLAN TO ACCOMPLISH YOUR OBJECTIVES?

Time spent would be divided in the following way:

- 1) July-August 2015. Publication of the iBook lab manual. This includes final filming of technical demonstrations, photographing images, and writing checkpoint questions that provide formative feedback to the students on technical skills and background knowledge. Requirements: Two undergraduate research assistants.
- 2) Fall term 2015. Generalizable scaffold for implementation in other labs. Requirements: One undergraduate research assistant.
- 3) Fall term 2015. Research specific modules. This will include discussions with interested labs and working with undergraduate student research assistants. Requirements: One undergraduate research assistant.
- 4) Winter term 2016. Working with identified projects in home department of Biology: Rosa da Silva, Joanna Wilson, Ana Campos, Robin Cameron. One student research assistant and/or a volunteer placement student per project. Requirements: Two undergraduate research assistants.
- 5) Spring 2016. Workshops and presentations on campus to identify new collaborations outside of the Department of Biology. Working directly with one member of the lab or an undergraduate student to develop the project specific requirements of the lab. Requirements: Two undergraduate research assistants.
- 6) Final month devoted to publication of work evaluating the pedagogical value of the iBook lab manual and the CUROPs and the research faculty perception of the experience.

#### PROJECT BUDGET

Item	Description of budget item	Cost
Undergraduate student research assistants (Est. \$11.25 per hour)	2 x 65 hours in Summer 2015 (iBook scaffold; bookends) 2 x 65 hours in Fall 2015 (lab specific skills; one collaboration) 2 x 65 hours in Winter 2016 (lab specific skills; one collaboration) 2 x 130 hours in Spring 2016 (new iBook collaborations) (Approximate cost given current rates; including benefits; hours and rates may be increased depending upon WorkStudy supplemental funding)	\$ 7 312
iPads (6)	A set of iPads to bring to workshops for demonstrations; use by student research assistants; 6 x \$400	\$ 2 400
MacBookAir (1)	One MacBookAir; iBooks Author runs on apple computers while the published and draft iBooks can be opened on iPads	\$ 1 250
Workshops	End of project workshop with Research Faculty interested in adopting the iBook lab manual to engage CUROPs	\$ 750
Invited speakers	“Engaging undergraduate students in authentic research”; Two invited speakers - one per term	\$ 2 500
Conference fees	Estimated 3 to 4 conferences in Spring/Summer 2015 (For K.Dej and one undergraduate thesis student)	\$ 600
Incentives	Correspondence and surveys from graduated students and current students iBook CUROPs. A small incentive will be offered for participation.	\$ 500
Teaching release	Sessional (3 units per term, 2 terms; benefits and supplemental fees included)	\$ 18 574
Student grant seed money	Groups of 3 to 5 students will be asked to submit proposals for evaluation to receive \$500 to \$1000 for project resources per group. 5 to 10 groups will be funded in total.	\$ 5 000
TOTAL		\$ 38 886

#### EXPECTED IMPACT ON STUDENT LEARNING

This project aims to enhance student learning by providing more opportunities to bring undergraduate students into the research lab and by providing researchers with the tools and the incentive. Within the year of

the fellowship, the impact of the CUROP experience on students in the Nematode Diversity project will be evaluated through an analysis of project feedback from students over the past five years. In addition, this project will provide the opportunity to go back and interview students that have since graduated in order to assess their perception of the value of authentic research on their university experiences and on their career paths. Questions of interest will focus upon (1) the value of the reviewable and interactive iBook to the student research experience (2) the value of the collaborative and group research experience for the students, (3) the impact on accessibility to authentic research experiences. Over time, research faculty who participate in the program will also be interviewed to assay their perception of the experience.

The positive outcomes to more students will occur as more labs adopt this approach and take on a higher number of undergraduates into their labs. Within this first year, CUROPs using the iBook lab manual will be developed in collaboration with research and teaching faculty in the Department of Biology. Four faculty have already indicated interest (Dr. J. Wilson, Dr. A. Campos, Dr. R. Cameron, and Dr. R. da Silva). Within a year, I believe that projects for the development of iBook lab manuals will begin in collaboration with interested research faculty outside of the Department of Biology. In the following years, I will aim to work with one lab per term.

## DISSEMINATION PLAN

The following are elements of the project that will be disseminated:

- Nematode Diversity Project iBook lab manual will be published through Apple and will be available at no cost. Non-Apple alternatives will be made available on my webpage at McMaster University and through the online forum for nematode research, Wormbook.
- A research papers describing the CUROP and iBook lab manual will be submitted for review in conjunction with an analysis of the effect of the project on student learning, engagement, experience, and career outcomes. An assessment of faculty perception of the students will also be included.
- A Departmental seminar will be given to talk about the CUROPs and the iBook lab manual.
- University-wide workshops and support will be available upon request to interested faculty.
- Presentations at conferences on Teaching and Learning in Spring/Summer 2016.
- Two guest lectures under the title: “Engaging undergraduate students in authentic research.”

## SUMMARY OF RESEARCH OUTCOMES

This project will provide evidence for the benefits of Collaborative Undergraduate Research Opportunities (CUROPs). Measurable benefits will be the increased number of students completing an authentic research experience and the increased engagement for project students working in collaboration with their peers. In addition, I will measure the benefits perceived by the students in the CUROP in comparison to a traditional lab experience. Finally, an important aspect of this project is to provide evidence that research faculty have a positive experience in using the iBook in combination with the CUROP and that they are willing to bring more UG students into the lab at different stages of their program. In the long-term, this may lead to the creation of more shared undergraduate research space to resource CUROPs in place of departmental-based and course-based lab facilities.

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