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Student Perceptions of Staged Transfer to Independent Research Skills During a Four-year Honours Science Undergraduate Program

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Abstract
We describe interim results of an ongoing longitudinal pedagogical study investigating the efficacy of the Honours Integrated Science Program (iSci). We describe the pedagogical methods we use to prompt research skill development in a model from instructor-dependence to independent original research. We also describe a tool we use to help students organise their group research during their first attempts. Finally, we discuss students' perceptions of how well iSci develops their research skills.

Our results show that students are attracted to the iSci program because of the opportunities for research-based learning and skills development. We also found that in-program students value research skill development as a tool for successful completion of their degree and for their future academic or career plans. We conclude that our study methods help identify areas where we can support our students by building their research confidence and, in particular, their time-management skills.

Nous présentons une description des résultats intérimaires d'une étude pédagogique longitudinale qui vise à évaluer l'efficacité du programme spécialisé intégré de sciences (iSci). Nous faisons une description des méthodes pédagogiques que nous utilisons pour déclencher le développement des compétences en recherche au sein d'un modèle qui va de la recherche qui dépend de l'instructeur à la recherche indépendante originale. Nous décrivons également un outil que nous utilisons pour aider les étudiants à organiser leur recherche par groupe au cours de leurs premières tentatives. Pour finir, nous discutons les perceptions des étudiants sur la manière dont le programme iSci développe leurs compétences en recherche.

Nos résultats indiquent que les étudiants sont attirés vers le programme iSci à cause des occasions d'apprentissage basé sur la recherche et de développement des compétences. Nous avons également remarqué que les étudiants inscrits au programme apprécient le développement de compétences en recherche en tant qu'outil qui leur servira à terminer leurs études et à obtenir leur diplôme, ou pour leurs projets de carrière, à l'avenir. En conclusion, nous déclarons que nos méthodes d'études aident à identifier les domaines où nous pouvons soutenir les étudiants en renforçant leur confiance en matière de recherche et, en particulier, leurs compétences en gestion du temps.

Keywords
science pedagogy, longitudinal study, research-based learning, undergraduate research

Cover Page Footnote
The authors would like to thank Dr. Carolyn H. Eyles for her support, comments and over-arching leadership and the rest of the iSci iCore and iTeach teams. We could not have collected all the student data without the aid of Kris Knorr and Greg Van Gastel of the McMaster Institute for Innovation and Excellence in Teaching and Learning. Dr. Karen Szala-Meneok was a major source of consult in the ethics process. We would also like to thank Drs. Derek Raine, Sarah Gretton, Cheryl Hurkett and Dylan Williams at the University of Leicester for collegial dialogue. Most of all, we wish to thank the students in the Integrated Science Program at McMaster University.

Research skills and experience are an important aspect of any career involving science, whether in academia, industry, education, or policy-making. In the 4-year Honours Integrated Science Program (iSci) at McMaster University, building students' research capacity and confidence is one of the cornerstones of the entire program.

iSci is an Honours undergraduate degree program which teaches a broad range of scientific disciplines using an innovative pedagogical design and delivery model we call "Research-based Integrated Education (RIE)." Enrollment in the iSci program is limited to 60 students per year and most students enter the program immediately after high school. iSci launched in 2009, and has produced three graduating classes as of this writing. The iSci program aims to achieve rich learning outcomes that blend disciplinary knowledge and perspectives with professional skills, and to train future scientific leaders who have a broad range of relevant literacies, plus specialised skills and knowledge. The program was designed from a clean sheet with these aims in mind.

For undergraduate students, involvement in research can have important benefits. Undergraduate exposure to research helps students appreciate and understand the research process (Linn, Palmer, Baranger, Gerard, & Stone, 2015), is associated with better average grades, and improves students' overall perceptions of the undergraduate experience (Bergren, Snover, & Breslow, 2007). Additionally, students with undergraduate research experience are more likely to indicate an intention to pursue graduate education (Eagan et al., 2013), continue with post-graduate research activity, and use faculty for job recommendations (Hathaway, Nagda, & Gregerman, 2002).

Our goal is to move students from their incoming high school research understanding (which we have found to be minimal and restricted to secondary literature searches) through to an independent, original research competence within four years. We see the research process as encompassing many important skills, habits, and processes that will be useful to all our students as lifelong learners, in that skills such as information sourcing and filtering will be important whatever their post-graduation destination. In placing a high level of support for research skills, and by explicitly discussing research attitudes, best practice, and societal meaning of scientific research, we also address the challenge of balancing "content pushing" versus students' personal experience of university which is facing institutions of Higher Education today (Healey & Jenkins, 2009; Jenkins & Healey, 2015).

We support students' progress by using RIE to build from Level I (literature-based research, some argument construction, some experimental design), through Level II (developing research questions, developing original models, data acquisition and analysis,), Level III (selection of research focus, greater choice, emphasis on communication of results to different audiences), and finally, to Level IV, an undergraduate thesis.

Our program is distinct from almost all other interdisciplinary science university-level offerings in that it incorporates all of the following features over a complete four-year program: true interdisciplinarity (not just multidisciplinarity), engagement with higher level content in all areas including mathematics, research connections across all four of the quadrants of the Healey model (see below), a strand of "Science Literacy" throughout which serves to integrate scientific knowledge with scientific practice, and transparent pedagogical innovation (including performing pedagogical research and the opportunity for students to become engaged in pedagogy and pedagogical research).

As instructors and designers in iSci's core teaching team, we are monitoring how our program is supporting students, with the goal of ongoing improvements and documenting the outcomes of our innovations. To this end, we began a longitudinal study of iSci in 2013. We chose

to narrow our research focus towards the notion of "student preparedness for the next academic step". The Study does not pre-judge what students' next steps should be, but collects data on current perceptions, future plans, and reflections on the utility of past program elements.
The study has been approved by McMaster's Research Ethics Board (certificate number 2013 056). We will first discuss the pedagogical foundations of the iSci program and then return to the longitudinal study's methods and results.

Pedagogical Methods

The decision to base learning in iSci around research projects was made very early on in the program's design phase (Eyles & Racine, 2007). The pedagogical underpinnings of the research projects were drawn from problem-based learning (Barrows, 1996) and inquiry methods (Haury, 1993) adapted for use in the program. A large body of literature exists explaining and evaluating this pedagogical area and the idea of linking research and teaching (Malcolm, 2013). There is not yet, however, a deep literature that documents and describes our specific kind of program structure. The University of Leicester's Interdisciplinary Science (now Natural Sciences) Program (University of Leicester, 2015) in the United Kingdom was a key influence and one of the author's experiences in developing methods and materials for that program provided a practical base which helped to speed up iSci development. In particular, structuring learning solely around complex, lengthy research projects required giving incoming students direction not only on project goals and requirements but also, crucially, on working practices and approach-planning techniques. Although most knowledge transfer from the Natural Sciences Program was achieved from practical experience within that program and from continuing collaborative interactions, some outcomes from the program have also been published (Gretton, Raine, & Bartle, 2014).

As described by Griffiths (2004) and advanced by Healey (2005), there are multiple ways to link research with teaching (Figure 1).

iSci's position in the Healey (2005) Model lies in the top right research-based quadrant ("curriculum emphasises students undertaking inquiry-based learning"), but with a strong leftwards pull towards the research-tutored quadrant ("curriculum emphasises learning focused on students writing and discussing papers or essays"). Individual activities within iSci may fall in any of the four quadrants.

All the instructors involved in iSci are active researchers. In addition, many of them are teaching specialists (two of the authors are teaching-stream faculty and two 3M Teaching Fellows are members of the instructional team) and all are interested in pedagogical innovation. The potential to shape strong future researchers and scientifically-literate members of society also offers us the opportunity to bring our own research interests into the classroom. However, making relevant and useful linkages between research practice and undergraduate teaching does not happen fortuitously, but must be "engineered" (Gibbs, 2010). We designed a scaffolding for our staged approach to building research skills that centres on research project design. The scaffolding was adapted from the LEICESTER model (Raine & Symons, 2005) in order to make it suitable for the length of projects and student numbers.

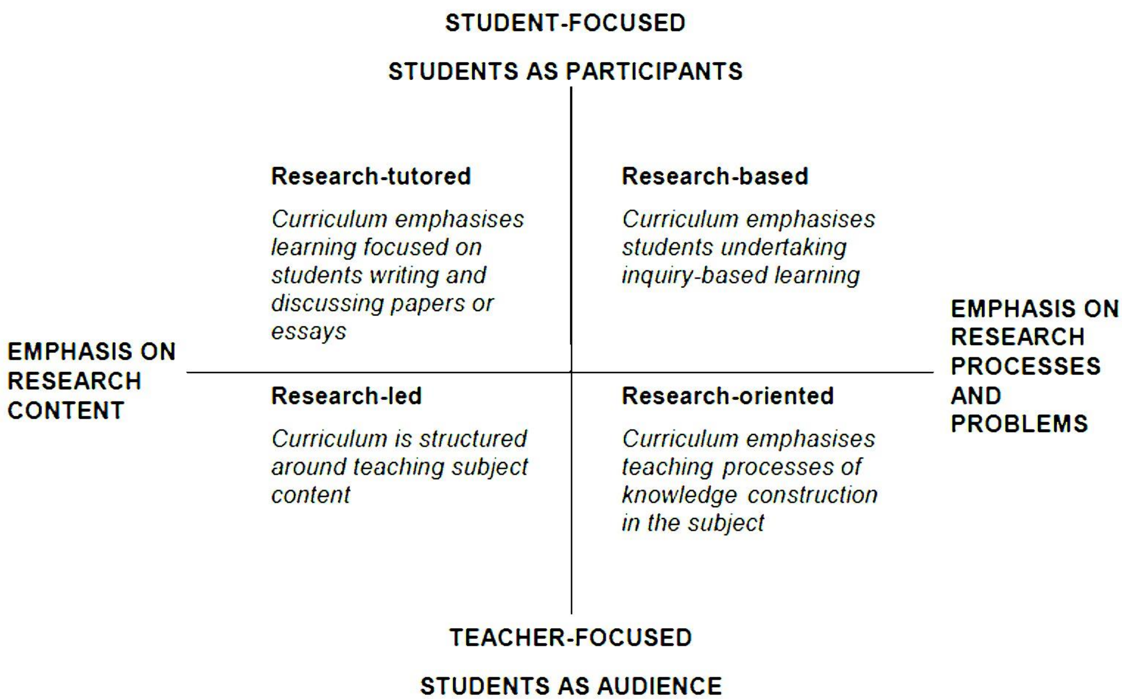

Figure 1. The Healey (2005) Model of interactions between research and learning in the classroom.

Each iSci research project is initiated by a project pack (similar to a mini course syllabus) that is authored by the instructional team. Each project pack includes sections outlining a project scenario, to intrigue students and set context, learning objectives in both content and skills across a range of disciplines, and specifications and rubrics for rich, real-world-like assessed major deliverables. These deliverables vary (e.g. scientific reports to different audiences, oral and poster presentations), and are usually authored by small groups, but may also include individual components to support knowledge and skill development. The pedagogical decisions involved in creating the projects and the project packs were informed by our practical experiences with problem-based learning and inquiry. However, we also wish to add a new dimension of "learning to research, by research." The resulting pedagogical model is new and still under development. It is being driven by pragmatic considerations of resourcing and fitness for purpose, with a lot of input from our network of instructors, institutional colleagues, and interactions with the wider higher education community (e.g., via conferences, visits, and informal interactions). Not all of these inputs have been captured in the educational literature.

The project packs are detailed, specific, and rather narrowly-framed in the first term of the first year, which includes a 10-day practice project and two, three-week group research projects. In the first year all research projects cover topics that are inherently interdisciplinary and cover concepts from six disciplines. From the second term of the first year through to the end of the third year, the project packs become decreasingly directive, allowing more flexibility for the approaches and outputs, within the specific research topics that groups and individuals can pursue (Figure 2).

In Level I, iSci students spend 24 hours per week in class or lab (they will usually take a 3-hour-per-week elective as well). The typical weekly contact time is broken down into six hours in the laboratory or field, two hours of class for each discipline element (mathematics, physics, chemistry, life science, Earth science and science literacy – some material will be project related, other will be foundational), five hours of supervised project time, and one hour for an invited speaker (project-related). Students spend at least 24 hours per week on private study and group project work outside class. The high amount of weekly contact time with a small, accessible group of instructors combined with the small class size (<60 students) builds a comfortable and interactive learning community. It fulfils the first of the Seven Principles of Good Practice in Undergraduate Education identified by the practical and widely known guidelines of Chickering and Gamson (1987), encouraging student-faculty contact, and facilitates the next three principles: encouraging cooperation among students, encouraging active learning, and giving prompt feedback.

In Level II, students have 18 contact hours per week, spent in the laboratory or field (six hours), math class (two hours), and on project content (10 hours). Students work on two projects at once, one that lasts the whole term and another that lasts about six weeks. Science literacy content is built into each project and there are also writing and other science communication activities outside class time (Symons, Colgoni, Harvey, & Eyles, 2012).

In Level III, contact time is reduced to 12 hours per week, which is divided evenly between two research projects running in parallel each term. Science literacy content is handled similarly to that in Level II. The project pack guidelines and project leaders' mentorship throughout Levels I to III reinforce Chickering and Gamson's (1987) sixth principle, communication of high expectations. This role is taken further by students' undergraduate thesis advisor in Level IV.

Outside the thesis work itself, class time in Level IV is restricted to about two hours per week for a skills development and thesis support seminar.

Each project has one or more "project leaders" who are members of the iSci instructional team. In Level I, the projects are led by instructional team members who are engaged in teaching one of the discipline areas (mathematics, physics, chemistry, life science, Earth science, and science literacy). In Levels II and III, leads are subject experts who conduct research in the field of the research project. The team leaders write the project packs and provide research support to students throughout the project. Project packs are reviewed annually, with small changes made motivated by logistical needs, student and instructor feedback, and the need to remain topical.

Even with carefully written project packs, however, the broad scope of the interdisciplinary research project areas in the first year would quickly swamp students. Learning from early experiences of students' project- and time-management capabilities in the Natural Sciences Program and other problem- and context-based learning projects at the University of Leicester (Williams, Woodward, Symons, & Davies, 2010), we therefore decided to develop a simple strategic planning tool which students are trained to use throughout Level 1, and is lightly assessed during their first two research projects. The tool is called the Research Project Protocol (RPP) and is a shared, constantly-updated document owned by a project group that is available to all members at any time, plus the project leaders (who can add feedback directly to the document). Students typically use Google Docs, a Wiki platform, or a OneNote folder to construct and share their RPP.

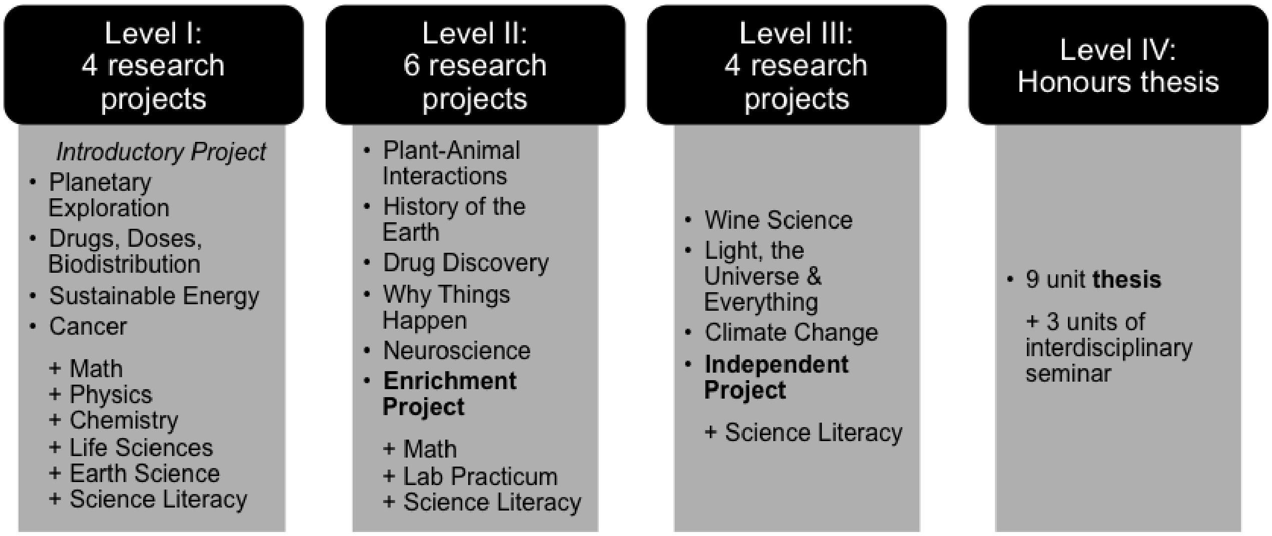

Figure 2. Research Projects in the iSci program (bullet points) for each level of the program. Opportunities for individual research are highlighted in bold. Other theory, skills and techniques strands are indicated by a + sign. Before the start of the first Level I research project, a practice *introductory project* is completed to familiarise students with how iSci research projects work. All students complete all of these program elements.

The RPP is a project management tool that consists of four sections:

1. Targets: Draft an agreed statement of group intentions. What are we being asked? What is the issue here?
2. Tools: Make an annotated list of existing knowledge, resources, and skills that are ready to use. What do we already know? What have we learned so far which applies?
3. Tasks: Make a list of learning objectives that we need to cover. What do we need to know? What must we learn in order to understand this? What skills do we need to complete the task? Which terms don't we understand?
4. Timeline: Draw up a detailed plan of action based on the schedule. How can we find out? Who do we need to consult? Which people are we scheduled to meet and what should we ask them? How shall we divide up the tasks? What sources of information can we use? What are our deadlines?

The RPP enables groups to develop a shared understanding of what is important to achieve, how much progress has been made towards the targets, outstanding tasks required, and a plan of who is doing what and when. One of the most important aspects of the RPP is that it encourages groups to set internal goals and deadlines over and above those specified in the project pack (which also emphasizes time on task, the fifth of Chickering and Gamson's (1987) principles). The development of the RPP was informed by previous work on similar tools (Raine & Symons, 2005; Williams et al., 2010).

Although the RPP plays an important role in helping students manage the "messiness" of research projects in Level I, by the third or fourth research project, the students are usually adapting, amending, and rearranging the structure in order to make it fit their working patterns for each new project, while still understanding that the purpose is not to impose an arbitrary "planning" task, but to actively engage in mindful, efficient project management. We encourage this and see it as a healthy sign that they feel in control of research processes and are adapting their approaches to fit different purposes and working styles. Groups will choose different media for the RPP depending on the project's particular requirements. This indicates an internalisation of the need to plan and a developed capacity for independently developing flexible working strategies. In projects in Levels II and III, the RPP is not a requirement and is not assessed. Students may still choose to use it. However, other assessed project deliverables such as research notebooks, proposals, and reflections continue to develop group and individual goal-setting, organizational, and project management skills.

By the last six weeks of Level II, students are ready to engage in their first individual research project, the "enrichment project", which allows them to investigate one aspect of their previous research projects in more depth. Each student selects a supervisor from among the Level II research project leaders. Enrichment projects tend to be literature-based or focused on materials design. Examples include: lab protocol design, small meta-analyses of current topics, and mathematical modelling testing foundational theories.

Individual research opportunities continue in the second half of Level III with a 10-week independent project under the supervision of an instructor (from the iSci teaching team or another McMaster faculty member). This project is worth about three credits (the same as a standard university course). The students have much more influence over their research question than in Level II and a wider range of approaches are available to them. This is also the point where they begin to learn about working with a supervisor and/or lab group.

Level IV includes a 9-credit Honours thesis, the highest level of undergraduate research. The research skills students developed in Levels I to III receive their most demanding test. Students can also directly compare their research competency with non-iSci students if there are other thesis students working with their supervisor.

The survey results that follow show a high level of common experience among our students, but our in-class experience as instructors and our individual interactions with students have shown that our students vary considerably in their personalities, aspirations, approaches, and research styles. In the design phase, we consciously added a lot of variety into the iSci program, particularly with regards to the types of assessed activities we set for the students. Chickering and Gamson's (1987) seventh and final principle, respecting diverse talents and ways of learning, was an aim from the beginning. Creating a diverse and rich program, however, meant that measuring "success", of the students and of the program alike, requires a thoughtful, incremental, and long-term approach.

Method

The iSci Longitudinal Study includes five survey points of in-program student attitudes and intentions: entry survey (taken within two weeks of arriving at university); three year-end surveys (end of Levels I, II, and III; taken in last two weeks of the year's teaching term); exit survey (program exit at end of Level IV; taken in last two weeks of the year's teaching term).

The core instructional team developed three questionnaires (entry, year end, and exit) that examine the notion of preparedness. Each iSci student is invited to participate and, upon consent, creates a confidentiality code that we can use to track their responses through each survey. In this way, we can identify how their goals, confidence, priorities, and skills progress as they move through the program. It is becoming common practice to offer academic credit for student participation in pedagogical studies (Ferrari & McGowan, 2002). The study is renewed with the McMaster Research Ethics board annually and students are re-informed of the study each year. We use participation in a pedagogical consent process as part of the overall learning experience for our students, exposing them to all varieties of academic research, in this case the concept of informed consent (Bowman & Waite, 2003). Indeed, many students go on to pursue independent, pedagogical research studies during the program. As iSci embeds research into every aspect and at every level, our study had to be broader-based than previous studies on students' exposure to research (Hathaway et al. (2002) and Bergren et al. (2007), for example, looked at the benefits associated with a limited-term research opportunity).

The surveys cover a broad range of topics and gather both quantitative and qualitative data. Here, we focus on questions which yield quantitative data on research skills (see Table 1 for the relevant questions). The questionnaires are wide-ranging, but for this investigation of the development of research skills, we will focus on those questions that indicate research intentions and preparedness, and research skill development and awareness. All of the questions we analysed here supplied quantitative data, mainly based on 7-point Likert scales.

The study began with a pilot phase in the academic year 2011-12, during which we tested the end-of-year instrument by including a feedback prompt for every question. Thus participants could choose to identify questions that were poorly worded or troublesome to answer accurately. The entry and exit surveys were based on a subset of the tested and corrected end-of-year survey, with additional questions that were pertinent to the entry or exit circumstances. In the two subsequent years, all three questionnaires have been administered. The exit questionnaire has therefore been used for both graduating cohorts, as the first graduates emerged from the program in summer 2013.

Table 1
Sample Questions from the Entry, Year End, And Exit Surveys. (All the sample questions listed here had 7-Point Likert scale responses.

Question *[with comments]*	Survey
Indicate the extent to which you feel high school has prepared you in research skills. *[Research skills was one of a list of skills.]*	entry
Indicate the extent to which research skills are important for you to learn and develop as part of iSci. *[Research skills was one of a list of skills.]*	entry, year end
Rate the extent to which you are confident that iSci is contributing to your learning and development in research skills. *[Research skills was one of a list of skills.]*	year end
Rate Group Research Projects on their effectiveness as teaching and learning methods. Specifically, consider how this method engaged you in course curricula and facilitated your learning of the associated concepts. *[Group and Individual Research Projects were two of a list of methods.]*	year end, exit
How well do you think iSci will have prepared you for what you intend to do after graduation? Select any paths that currently interest you. Choose N/A for those paths that you are unlikely to pursue. ☐ Graduate school ☐ Teacher's College ☐ Law school ☐ School in a health-related field (medicine, dentistry, nursing, pharmacy etc.) ☐ Veterinary school ☐ Business school or accountancy or similar ☐ Employment in a program-related field ☐ Employment in a non-program-related field	year end, exit
How well did iSci prepare you for working on your final year thesis? ☐ Working with a supervisor ☐ Working in a research lab/group ☐ Managing your time in extended research ☐ Thesis writing ☐ General research process	exit

Results

Demographics

The composition of the respondents to the surveys is as follows:

> **(a) Entry survey:** two years of data (2013 and 2014 entries) collected so far. N = 94, a response rate of 95% (students are keen to participate when they enter and they also receive a small mark for completing the informed consent process, whether or not they choose to participate in the Study).

(b) End-of-year surveys: three years of data, each containing responses from students in Levels I, II, and III. N = 272, with an aggregated response rate of 80%.
(c) Exit survey: two years of data (2013 and 2014 graduating classes, the first two cohorts to graduate from the iSci program). N = 43, response rate 78%.

In the results below, the N will be variable because of several factors. When the Study began, we only had students in Levels I and II of the program, so N will be larger for questions dealing with lower level material. All questions are optional and most contain a null answer, but students may choose not to select the null answer. Some of the questions select a subset of participants: “If you are thinking of X, what is your reaction to Y?”.

Two cohorts have now graduated from the program. We present the following data (Figures 3 and 4) to indicate how many of them enter a research-intensive onward career and the relative proportions of the science disciplines those students who advance to graduate school engage in.

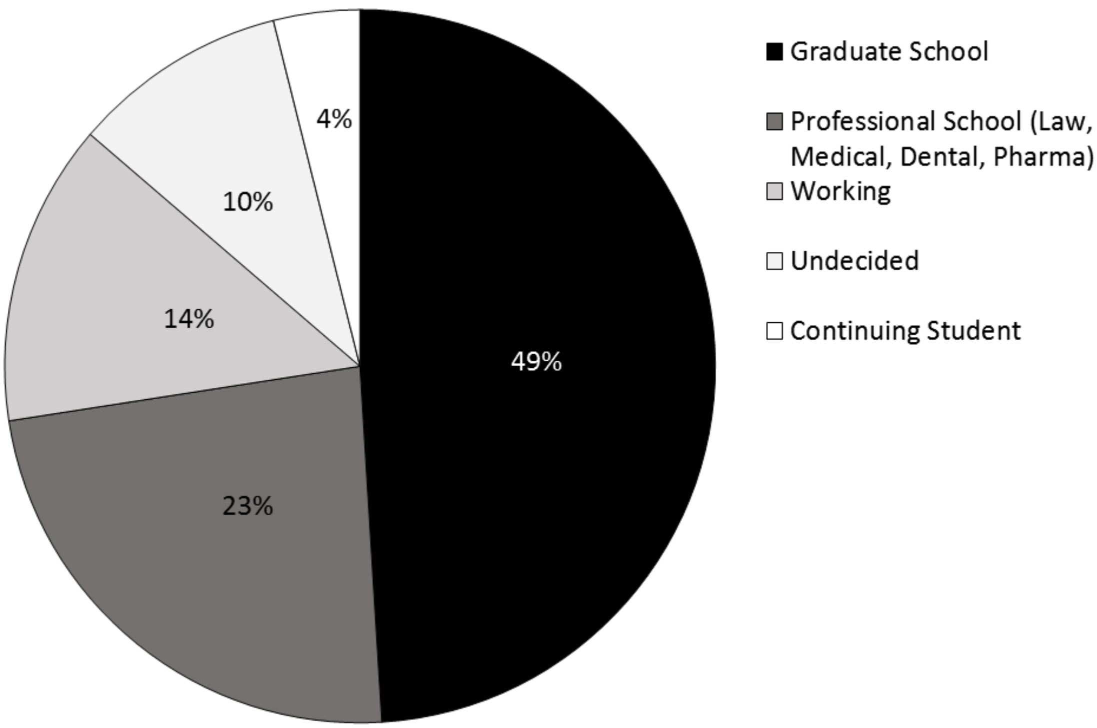

Figure 3. Destinations for iSci graduate students. (*N* = 51) Legend categories presented in descending order of percentage.

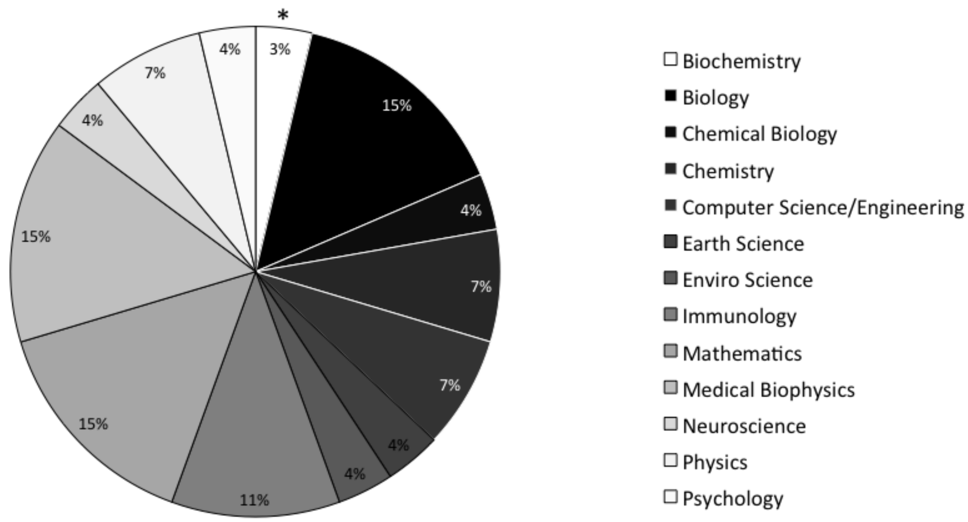

Figure 4. Subject areas of iSci graduates continuing in academia at the postgraduate level. (N = 25 students;13 discipline areas). Legend categories clockwise from asterisk.

Program Entry Survey Responses

We asked students: "What attracted you to iSci? (Choose the three aspects that were most important to you.)". We derived a set of possible responses directly from the program's aims, as set by the Faculty of Science, so that we could see which of the categories were meaningful in students' program selection:

- ☐ Interdisciplinary learning,
- ☐ Opportunities for group work,
- ☐ Learning through research projects,
- ☐ Learning research techniques,
- ☐ Variety of disciplines covered,
- ☐ Small class sizes,
- ☐ Working closely with faculty,
- ☐ Reputation of the iSci program,
- ☐ Teaching of the program fits with your learning style.

Thirty-three percent of respondents selected "Learning through research projects" as one of their three options, while 34% selected "Learning research techniques"; 9% chose both.

Thinking back to high school as preparation for university, we asked "Indicate the extent to which you feel high school has prepared you in research skills". Only 18% of students felt "prepared" or very well prepared (Figure 5).

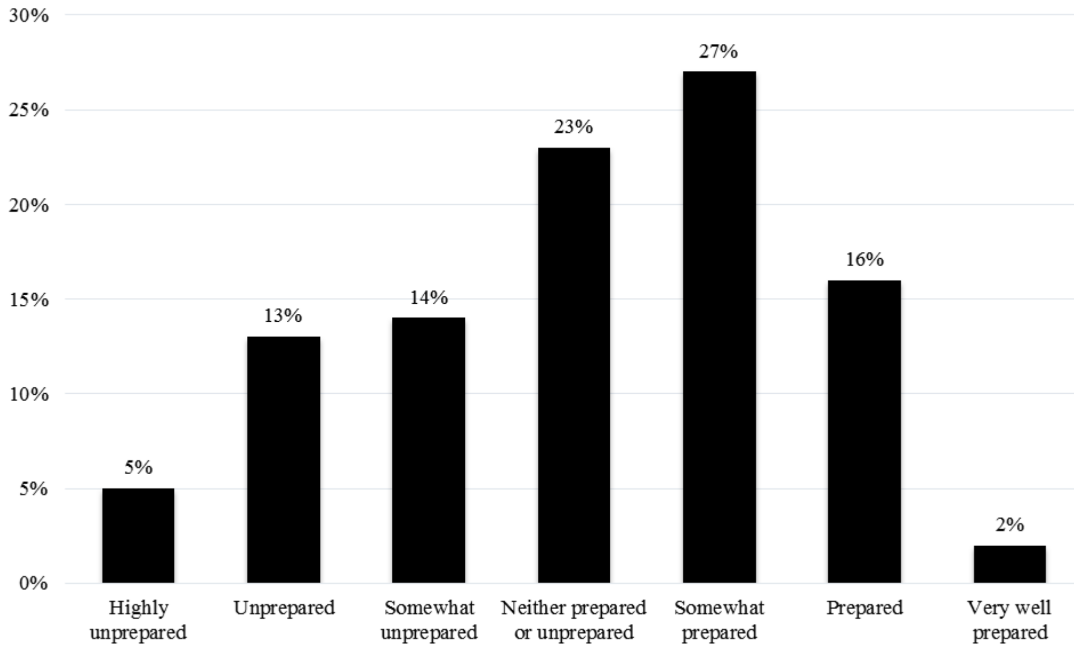

Figure 5. The extent to which incoming iSci students feel that high school has prepared their research skills, captured via 7-point Likert scale survey responses. (*N* = 91)

We also investigated students' perception of research skills as an important component of the iSci program. After just a few days in the program, the focus on research skills was evident, with not one respondent believing them to be unimportant to success in iSci, and 57% rating them "very important" (Table 2).

Table 2
The Extent to Which Incoming Students Believe it is Important for them to Learn and Develop Research Skills as Part of iSci. (N = 93)

Rating	Percent
Very important	57%
Important	29%
Somewhat important	12%
Neutral	1%
Somewhat unimportant	0%
Unimportant	0%
Completely unimportant	0%

Survey Responses About Graduate School Intentions

We asked incoming and in-program students "How well do you think iSci will prepare you for graduate school?" with a follow-up question to students who are considering graduate school on feelings of preparedness. Respondents were not limited to a single destination choice and were invited to indicate any that they were considering (Table 3).

Table 3
Percentage of Students Considering Attending Graduate School Post-iSci and Student Perception of How Well the Program Will Prepare them for Graduate School

	N	Considering grad school	Highly unprepared	Unprepared	Somewhat unprepared	Neither prepared or unprepared	Somewhat prepared	Prepared	Very well prepared
On Entry	95	97%	0%	0%	0%	0%	3%	25%	72%
End of Level I	126	86%	0%	0%	1%	4%	16%	34%	45%
End of Level II	90	84%	0%	0%	0%	5%	17%	41%	37%
End of Level III	55	87%	0%	2%	4%	4%	21%	38%	31%
End of Level IV	40	90%	6%	0%	0%	6%	11%	44%	33%
Overall	406	89%	1%	0%	1%	3%	13%	35%	47%

Tracked Survey Responses

We asked students to respond to two questions throughout their iSci experience, and thus could track their changing answers as they progressed through the Levels:

1. Indicate the extent to which research skills are important for you to learn and develop as part of iSci.
2. Rate the extent to which you are confident that iSci is developing your research skills.

Perceived importance of research skills over time. Seventy-two students supplied data that could be tracked over two or three years. Their responses were characterised as either "research skills are increasingly important" (i.e. their responses moved up the Likert scale from first tracked year to last tracked year), "research skills are decreasingly important" (i.e. their responses moved down the Likert scale from first tracked year to last tracked year), or their response was stable (i.e. no aggregate change on the Likert scale from first tracked year to last tracked year) (Table 4).

Table 4
Perceived Importance of Research Skills Over Time (N = 72)

Change in Importance	Percent
Increased	36%
Remained stable	43%
Decreased	21%

Overall responses to the question "Indicate the extent to which research skills are important for you to learn and develop as part of iSci" are shown in Table 5. Together with the responses on entry to the program (Table 1), we see the small changes in perception reflected in the "very important" and "important" categories. This indicates that the movements in Table 3 are not drastic and probably indicate a majority of the changes were a step from one category to an adjacent category.

Table 5
Perceived Importance of Research Skills (N = 362)

Importance Rating	Percent
Very important	51%
Important	35%
Somewhat important	11%
Neutral	2%
Somewhat unimportant	1%
Unimportant	0%
Completely unimportant	0%

Overall responses to the question “Indicate the extent to which you are confident that iSci is contributing to your research skills” are shown in Table 6.

Table 6
Perceived Confidence that iSci is Contributing to Research Skills (N = 350)

Confidence Rating	Percent
Very confident	43%
Confident	35%
Somewhat confident	16%
Neutral	4%
Somewhat lacking confidence	0%
Lacking confidence	2%
Completely lacking confidence	0%

Ninety students supplied data that could be tracked over two or three years. We were interested in seeing how student replies to this question changed over time. Responses were characterised as either “I am increasingly confident that iSci is developing my research skills” (i.e. their responses moved up the Likert scale from first tracked year to last tracked year), “I am decreasingly confident that iSci is developing my research skills” (i.e. their responses moved down the Likert scale from first tracked year to last tracked year), or their response was stable (i.e. no aggregate change on the Likert scale from first tracked year to last tracked year) (Table 7).

Table 7
Change in Perceived Confidence that iSci is Developing Research Skills (N = 91)

Change in Confidence	Percent
Increased	23%
Remained stable	51%
Decreased	26%

Exit Survey Responses

We asked students "How well did iSci prepare you for working on your final year thesis?" We focused on five major ingredients common to all science thesis work: working with a supervisor, working in a research group or laboratory, time management, thesis writing, and the general research process. All ingredients indicated a confidence in being prepared, but thesis writing was the most clearly successfully and time management the least (Figure 6).

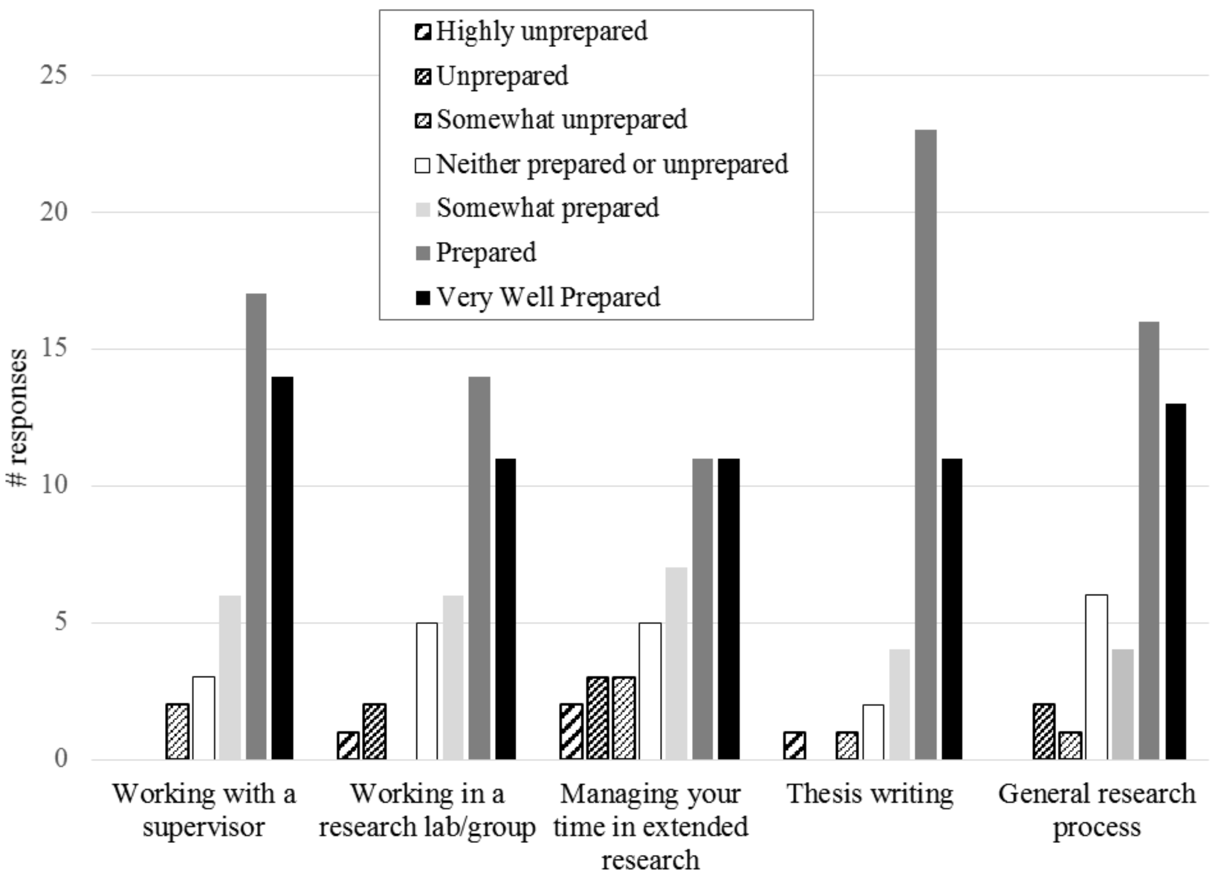

Figure 6. Graduating students respond to prompts about how well iSci prepared them for working on their undergraduate thesis, the most extensive individual original research activity in iSci. (N = 42)

Discussion

Our entry survey results demonstrate that learning-by-research and the opportunity to build research skills are key attractions in students' decision to enter the iSci program. Although the incoming students clearly value research skills, their assessment of the level of research-preparedness imparted by their high school experiences is quite low, with 32% of students arriving at university feeling unprepared to a greater or lesser extent. iSci recruitment material makes it clear that iSci has a strong research focus, and incoming students almost unanimously (99%) demonstrate recognition that strong research skills will be needed to succeed in the program. They are also very likely to have already identified a research-facing destination after iSci, with 97% of incoming respondents considering graduate school as one of their potential destinations. This result is rather surprising: students often enter the Faculty of Science at McMaster University with the stated intent of gaining entry to a health-related professional school, so we would expect that option to garner a greater response rate than graduate school. In reality, 9% of incoming iSci students had no current intention of applying to a health-related professional school whereas only 3% of incoming iSci students discounted graduate school as a probable destination.

Data from higher levels of the program show that interest in attending graduate school declines (reaching a low of 84% at the end of Level II) then rises to approximately the same intensity by program exit. However, destination data shows that only around 50% of students in the two graduating cohorts so far actually secure places at graduate school. This indicates that graduate school is seen by the majority of iSci students as a realistic possible outcome, but is not necessarily their first choice of destination.

In the longitudinal study, we use "preparedness for graduate school" as a proxy for how well students feel that they are progressing with their research skills as they move through the program. Looking at the importance that students attach to research skills, we again see that the in-program students, just like the incoming students, are almost unanimous in their view that research skills are the key to success in iSci. The responses from students feeling less than prepared for graduate school are therefore interesting and with low numbers of students falling into this category may be due more to individual experiences and attitudes than to systemic failures. As instructors, we can guess from personal interactions with students that, on average, iSci students may be more self-critical than non-iSci students, or simply more aware of the challenges of graduate school than others, thus driving their confidence down even when their abilities are more than adequate. The survey does not allow us to investigate these factors.

The raw numbers suggest that overall, the student body is similarly satisfied that iSci is giving them the opportunities and support they need to develop their skills. The tracked data, however, shows that their confidence in the program is not always steady. Although 23% of students who responded on more than one occasion to the relevant questions say that their confidence in iSci's ability to build their research skills increased over time, 26% felt the opposite.

We found that 26% of students felt less confident over time that iSci was developing research skills, which initially give cause for concern. Taken in conjunction with Table 6, the clustering of responses suggests that movement up or down the scale is mostly restricted to an adjacent step, the greatest amount of which would be contained within the positive (neutral or better) set of responses. Also, it is hard to characterise what a one Likert step decrease in confidence really demonstrates; it could be variance in categorisation, or it could be an increased understanding of the complexities of research, leading to a more mature response of "I thought I could do everything, but now I realise there is much more to learn."

The reasons for this result may be complex. First, the magnitude of the shift is not taken into consideration here so the effect of a student stating for two years that they feel "very confident" followed by a single response of "confident" and a student moving from "very confident" to "unconfident" are given equal weight here. Given Likert-scale responses, the shift is impossible to quantify in a meaningful way. Equally well, students may simply become more demanding, discerning, and even anxious as they approach graduation, which could also explain this result.

Our best in-program gauge of how comfortable students feel in "real" research situations by the end of the program are given by responses to the questions which probe how well-prepared the students felt for their undergraduate thesis. Here, the results are generally enthusiastic. The benefits of performing an enrichment project in Level II and a one-term independent research project in Level III feed particularly into the categories "working with a supervisor" and "working in a lab or group". iSci's varied research project deliverables and focus on developing science communication skills have built a remarkable strength in readiness for thesis writing. Project management scaffolding, in the form of the Research Project Protocol and subsequent organisational tasks, have helped students feel fairly confident on entering their thesis work, but time management (instructors and students both acknowledge) is a skill students struggle with the most. Finally, the students' confidence in their overall research skills is strong, with no students reporting feelings of total unpreparedness.

In addition to the added insight into the strengths and weakness of our program that analysis of students' responses gives, we also have used the study as a reflective mechanism for our own teaching and pedagogical development. As busy instructors, our focus must necessarily be on a day-to-day level on what we must "do" next and how we should achieve it, with only small amounts of time being allocated to thinking about "why" we might choose one method over another, or how we know whether we have succeeded in what we attempted. Perhaps there are two results arising from this study which are mostly unquantifiable yet in many ways equally as important as the quantitative evidence of our successes or failures detailed above. One, that in thinking about the questions we wished to answer in the longitudinal study, we were forced to take stock of exactly want we want the program to achieve in the long term (i.e. well beyond the normal scope of course evaluations) and how we could check our goals matched up with the reality of the student experience; and two, that in exhibiting our interest in student learning in this way, with students being invited to participate in the study from the moment they arrived in program through to keeping in touch with alumni for future surveys, we have created a virtuous cycle of reflective pedagogy which has transferred to our students in ways we had not expected. In seeing us engaged in this research, our students' view of us as professional models has become broader. One aspect of this is visible: we estimate (from our personal lists of students we have supervised) 10% of iSci students select pedagogical topics for one or more of their upper level independent research projects where they are given broad flexibility of research fields. Both of these outcomes, we believe, would be applicable to other multi-year programs that engage in longitudinal evaluative activities.

Conclusions and Future Work

These results provide us with some evidence that students in all stages of the iSci program desire, value, and build research skills. By beginning in Level I with a guided structure and a focus on thinking about how to approach complex tasks, we give our students confidence. In Levels II and III, students add more skills and feel capable of exploring a little on their own, devising their own research questions and experiments, and performing their first independent research. In Level IV, the students tackle their undergraduate thesis feeling well prepared for all areas of the task. This staged approach was built into the iSci program from the beginning, but it is only after two graduating classes that instructors, supervisors, and students alike can see how far-ranging the benefits of the approach are.

Our longitudinal study also helps us to identify areas in which we can improve our student support. Here, time management is identified as perhaps the key research skill we should strengthen and explore more with the students.

An aspect not discussed in this paper is that the longitudinal study provides comparative data from non-iSci science students. A future extension of this investigation will look at whether iSci students' perceptions of undergraduate research differ markedly from their peers. We are also extending the longitudinal study to survey iSci alumni at one, three, and five years after graduation. The alumni data set will help us to identify aspects of iSci which are particularly helpful in various career options, but will also help us to support a core of skills development with the widest and strongest applicability to iSci program graduates.

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