Science Inquiry in First Year at McMaster University

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Presentation in Two Parts

- Part 1: Year 1 Inquiry Course at McMaster
- Part 2: ***iSci*** - New 4-year integrated science program currently under development that is heavily based on Inquiry methods.

Definition of Inquiry

In an Inquiry course students:

- Identify what they want to learn
- Formulate a question
- Answer the question
- Communicate the answer effectively

Centre for Leadership in Learning – resources:

http://www.mcmaster.ca/cll/inquiry/index.htm

Inquiry as a Teaching Form at McMaster

- Teaching innovations in the Medical School (mid ’70s)
- Evolution of medical education into Problem-based Learning (PBL) and Inquiry formats (’70s and ’80s)
- Problem-solving methods developed in ’80s
  - (e.g., Don Woods, Chemical Engineering)
- Inquiry courses introduced in Level 4 Science (early ’90s)
- Inquiry courses introduced in Level 1 (late ’90s)
  - Faculties of Science and Social Sciences only

Year 1 Science Inquiry at McMaster

- How does it work?
- Does it work?
- How do we know it works?

What should students learn in Inquiry?

- To learn how to ask a "good question."
- To learn how to find resources to answer the question.
- To learn how to work alone *and* together in peer groups
- To learn how to present the answer(s) to their question.
- In short, to learn how to do research and develop useful skills that can be applied in any working environment.

Year 1 Science Inquiry Course Format

- "One term" credit course - spread over 2 terms
- Enrolment limited to ~25 students/section
- 1 hour/week in Fall Term
  - Introduction to university life
  - Simple Inquiry exercises
  - Introduction to library and learning resources
- 2 hour/week in Winter Term
  - 2 Major research projects with presentations
- 3 *Peer Tutors* per section (upper year students who receive academic credit for this work)

Science Inquiry Instructors Work as a Team

- Research-active, tenure-stream faculty; 3-year "rotation" of instructors.
- Instructors from all science disciplines (Inquiry is *not* content-driven).
- Instructors meet weekly to share ideas and creatively plagiarize (from each other!).
- Benefits for instructors:
  - Acquire deeper appreciation of undergrads' needs, interests, and limitations.
  - Learn about the cultures of other disciplines.
  - Pedagogical diffusion back to other colleagues and more traditional modes of teaching and learning.

Term 1 – Inquiry Skills Development

- Library tours and library skills development.
- Debunking the myth of information on the “web.”
- In-class exercises to develop question-posing skills.
- Introduction to web-based communications tool.
- Exercises each week - posted on class web site.
- Two-week mini-poster project at end of term (done in groups of 2-3).

Term 1 Library Exercise (Scavenger Hunt)

Answer the questions below by using library resources. You may need to visit more than one library. Please indicate how you found each answer. Note that there is more than one way to find most of the answers.

- Provide the title, author and call number for a book that addresses *Chaos Theory* or *Supernovae* or *Population Dynamics* or *Organo-metallic Chemistry*. What is the title of the second chapter of this book?
- Who is/are the author(s) of the second Reports article in the Sept. 3, 2004 issue of ***Science***?
- In which of McMaster's libraries would you find books by B.F. Skinner?
- Cite a publication authored by a McMaster chemist in 2006. Give names of all authors, title of article, name of journal, year, volume, and pages.

Term 1 Library Exercise (Scavenger Hunt - 2)

- Find a citation for an article that addresses the effects of horror films on adolescents. Give names of all authors, title of article, name of journal, year, volume, and pages.
- What is the title of the lead article in the issue of *The Journal of Popular Film and Television* that is dated closest to your 16th birthday?
- With a browser, go to Find the Electronic Resources. Click. Select subject area: Science and Technology. Click on "S". Find "Scientific American". Click on it. What is the URL for their web-site?
- What is the title on the cover of ***Cell*,** Volume 113: 4 April 2003 and ***Cell*,** Volume 114: 22 August 2003?
- Who is the Editor of ***Cell***?

Term 1: One-Minute Talks (Ice-Breakers)

Coffee	Hangover cures
Hands	SUVs
My pet dog (or cat)	The last book (non-textbook) I read
The place I most want to visit	My comfort food
The Prime Minister	The NHL
Movie my parents should see	Homeless people
My ideal summer job	West Nile Virus
My worst job	Historical figure I admire most
Best (or worst) technology	My computer
Best thing about Canada	Global Warming & the Arctic

Term 1 Group Activity - "Fermi" Problems

- How long will it take to fill up my backyard swimming pool with a garden hose?
- What is the average power output in watts of a typical adult human?
- *(The classic!)* How many piano tuners are there in Chicago?

Term 1 Exercise: Interview a Researcher

- You will be interviewing a research scientist in the Faculty of Science. Each group will be randomly assigned an *aspect of research* (see the following page for a list) to cover in their interview.
- It will be your responsibility as a group to identify the appropriate member of the Faculty and to contact them in order to arrange an interview (which should last no longer than 30 minutes). We will discuss in class how to approach professors in the Faculty.
- The topic of research can be used to illustrate the aspect, but the aspect of research is to be the main focus of the presentation and handout.

Interview a Researcher – Aspects of Research

- Formulating good research questions
- Applying for research grants
- Collaborating with other researchers
- Supervising graduate students
- Preparing for and attending conferences
- Getting a paper published
- Doing research in the lab, working in the field or working at another laboratory.

Two Projects Done in Term 2

- **First Project: a group poster project**
  - Teaches students how to prepare a scientific poster.
  - First test of integration of inquiry skills.
  - Challenge is to get all their information in a predetermined area.
  - Clear rules for poster preparation provided – size, font sizes, etc.
  - Evaluation by students, peer tutors and instructor.

- **Second Project: an oral presentation by group.**
  - Second opportunity to integrate Inquiry skills in a project.
  - Oral presentation skills highlighted.
  - All students must participate equally in presentation.
  - All students marked individually – grading by students, peer tutors and instructor collated and used in overall evaluation.

Identifying a Good Question for a Project

- Most challenging aspect of course.
- Students work in groups to decide their own direction.
- Students must access current scientific literature.
- Students must “vet” project idea with instructor.
- Some groups identify “questions” early – some groups have difficulties – some groups can’t agree on question.
- Assistance provided by instructors and peer tutors – in class, *via* e-mail or *via* web-based tools.

Project 1: Poster Conference – Scientific Approaches to Major Global Challenges

- Climate change and alternative energy sources
- Communicable diseases (viral, bacterial, or parasitic; exclude the tremendous problem of AIDS)
- Malnutrition and hunger
- Sanitation and drinking water
- Pollution and environmental degradation

Project 1: Poster Conference – Scientific Approaches to Major Global Challenges

General Guidelines for Poster Project

- Focus on scientific or technical solutions to your problem - not social, psychological or political solutions.
- Your solution needs not be “global” but could address a “local” instance of the problem.
- Be sure to describe the magnitude of the problem and its consequences in terms of lives lost, money lost, property damage, *etc.*
- Describe *specifically and quantitatively* how your proposed solutions will help to alleviate the problems.

Project 1: Poster Conference – Scientific Approaches to Major Global Challenges

- **Rating the posters:**
  - Instructor, Peer Tutors, and all students evaluate posters.
  - “Rotate” (10-15 minute intervals) through (a subset of) posters and complete rating forms.
- **Peer Assessment and Self-Assessment**
  - Students privately rate their own contributions and the contributions of the other members of their group to their poster.

Project 2: The Major Project of the Year

- Builds on all of the previous Inquiry skills.
- Students work in newly formed groups.
- Students are now more self-directed, independent.
- Peer tutors and Instructor monitor progress of groups. carefully, looking for “danger signs.”
- Most students understand what they are doing now and are keen to do very well – a few still don’t “get it.”
- Project 2 presentations can be amazingly good.

Evaluation of Performance in Inquiry

- **Criterion:**
  - Students must provide evidence of mastery of Inquiry skills.
    - Three interviews during year: Christmas, late Feb. and early April.

- **Evaluation:**
  - It should be apparent to the instructor, peer tutors and an "intelligent observer" that a given student has developed Inquiry skills with:
    - Good to excellent proficiency; knows limitations and has worked hard to improve them. **Grade of A.**
    - Reasonable to average proficiency; has a number of areas for improvement of skills that are being addressed. **Grade of B.**
    - Mediocre proficiency; has areas that need improvement but has done little to make any improvement. **Grade of C or D.**

Evaluation of Performance in Inquiry

- Evaluation (in part): 30 min. interviews with each student
  - Instructor, 1-2 peer tutors present.
  - Set of similar questions asked of all students.
  - Opportunity to see how student groups performed and who did what.

- Written materials, posters and presentations evaluated:
  - Peer tutors evaluations very useful.
  - Peer tutors see another side of the students' performance.
  - Peer student evaluations also often revealing as to who contributed to the projects.
  - Final grades set in consultation with peer tutors.

Does Inquiry Improve Student Learning?

- Does "exposure" to the Inquiry format improve a student's abilities to read, think, research and formulate ideas?
  - How would you evaluate this "improvement"?
  - Are these skills developed in "non-Inquiry" students?
  - Are Inquiry skills valuable to students?
  - Is it worth our effort to provide this sort of attention to students?
  - Can we do "Inquiry" in another, less-demanding format?

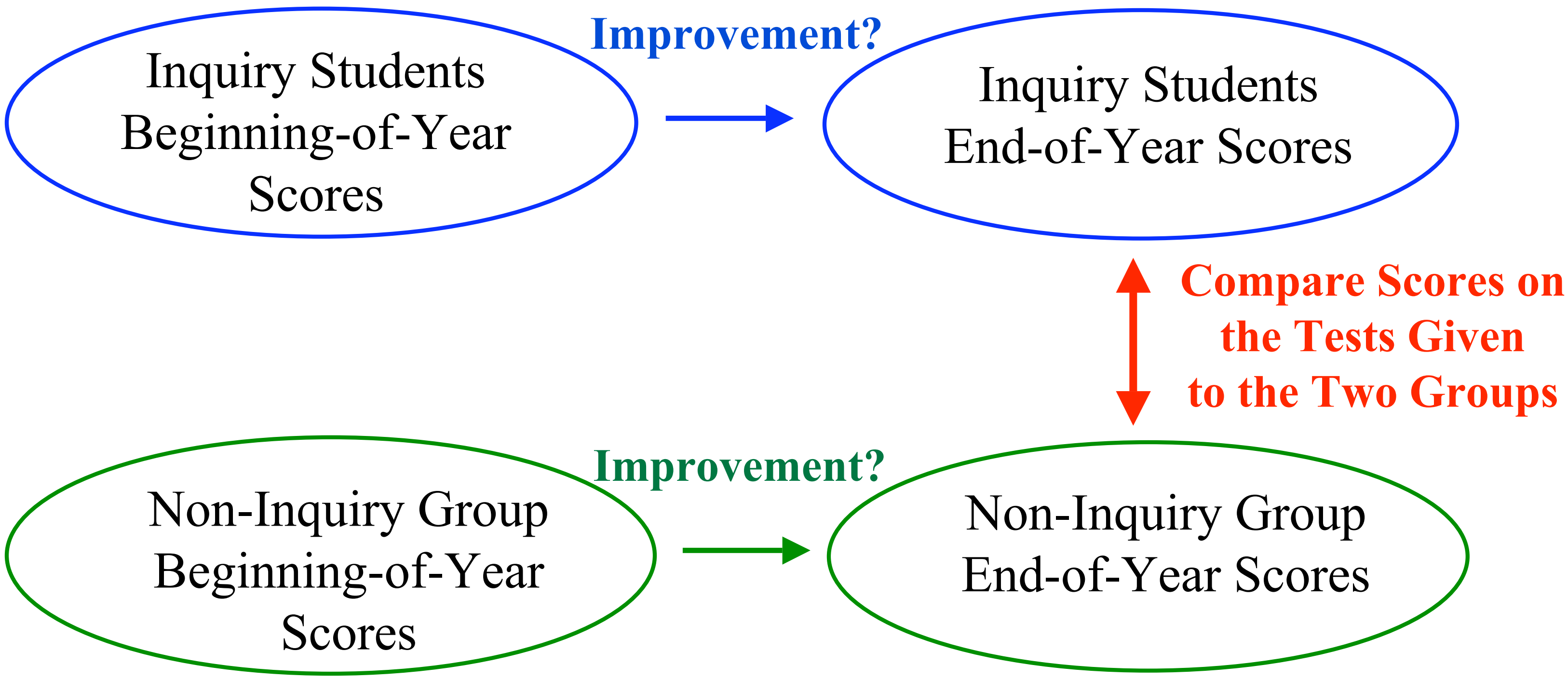
Evaluation of Inquiry Course Instruction

- Ms. Kristina Trim has just completed a Ph.D. degree at McMaster doing a project to answer these questions.

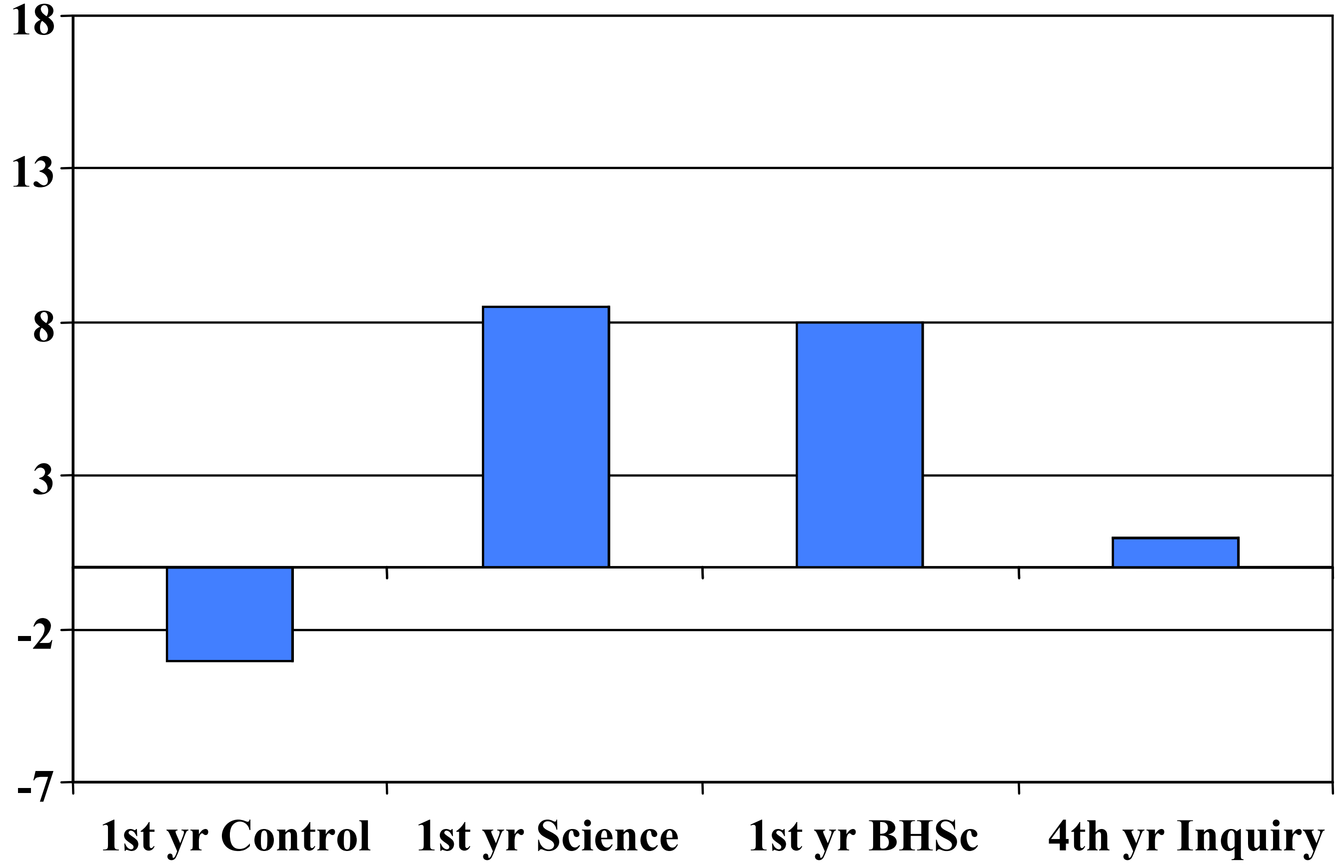
- Students in two Inquiry environments were tested alongside two groups of "non-Inquiry" students:
  - Inquiry Students:
    - Year 1 Science Inquiry students (n~300)
    - Year 1 Bachelor of Health Sciences students (n~300)
  - "Non-Inquiry" Students:
    - Year 4 Science students who have done some Inquiry (n~360)
    - Year 1 Science students with no Inquiry experience (n~120)

Research Design for Three-Year Study

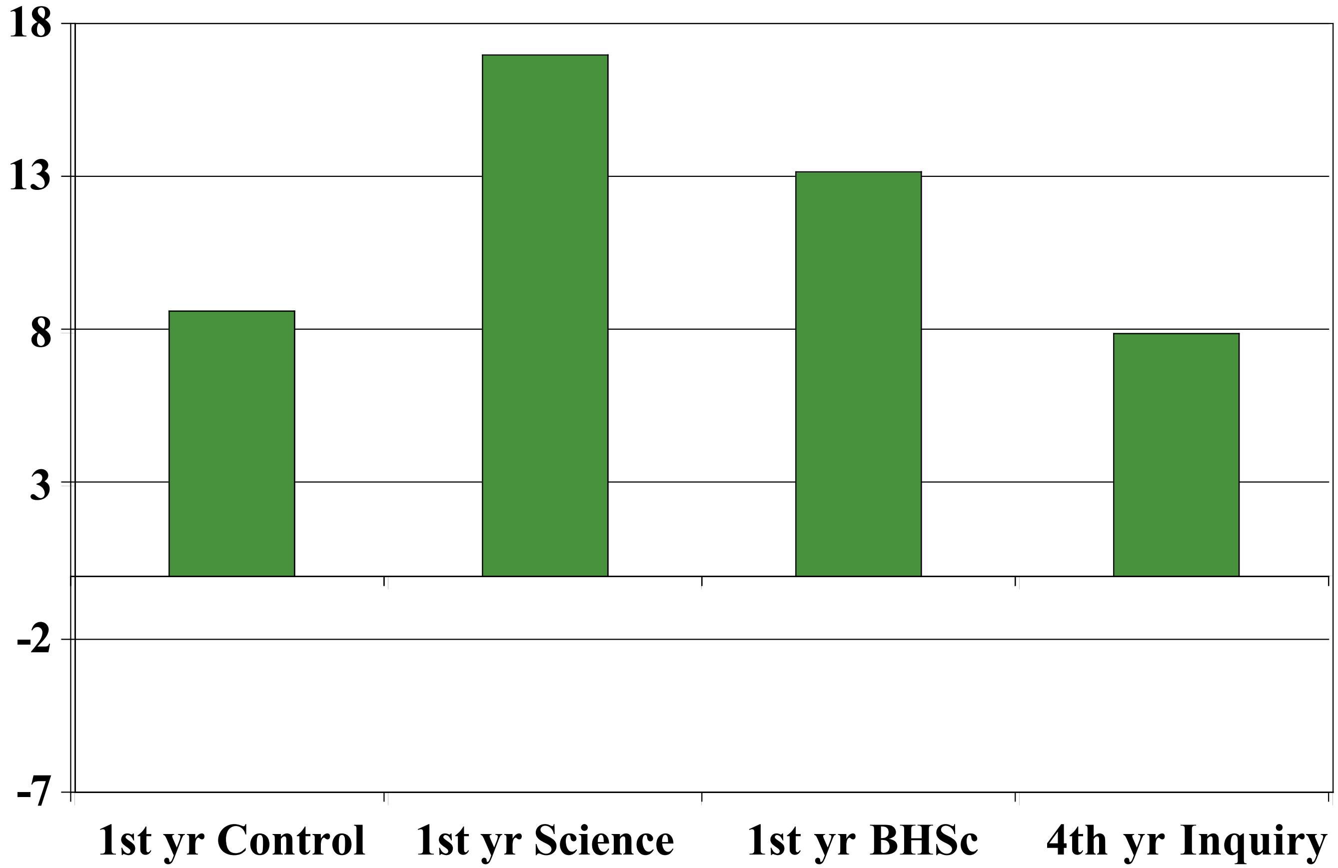
Tests given in September and in March to evaluate 9 learning outcomes:



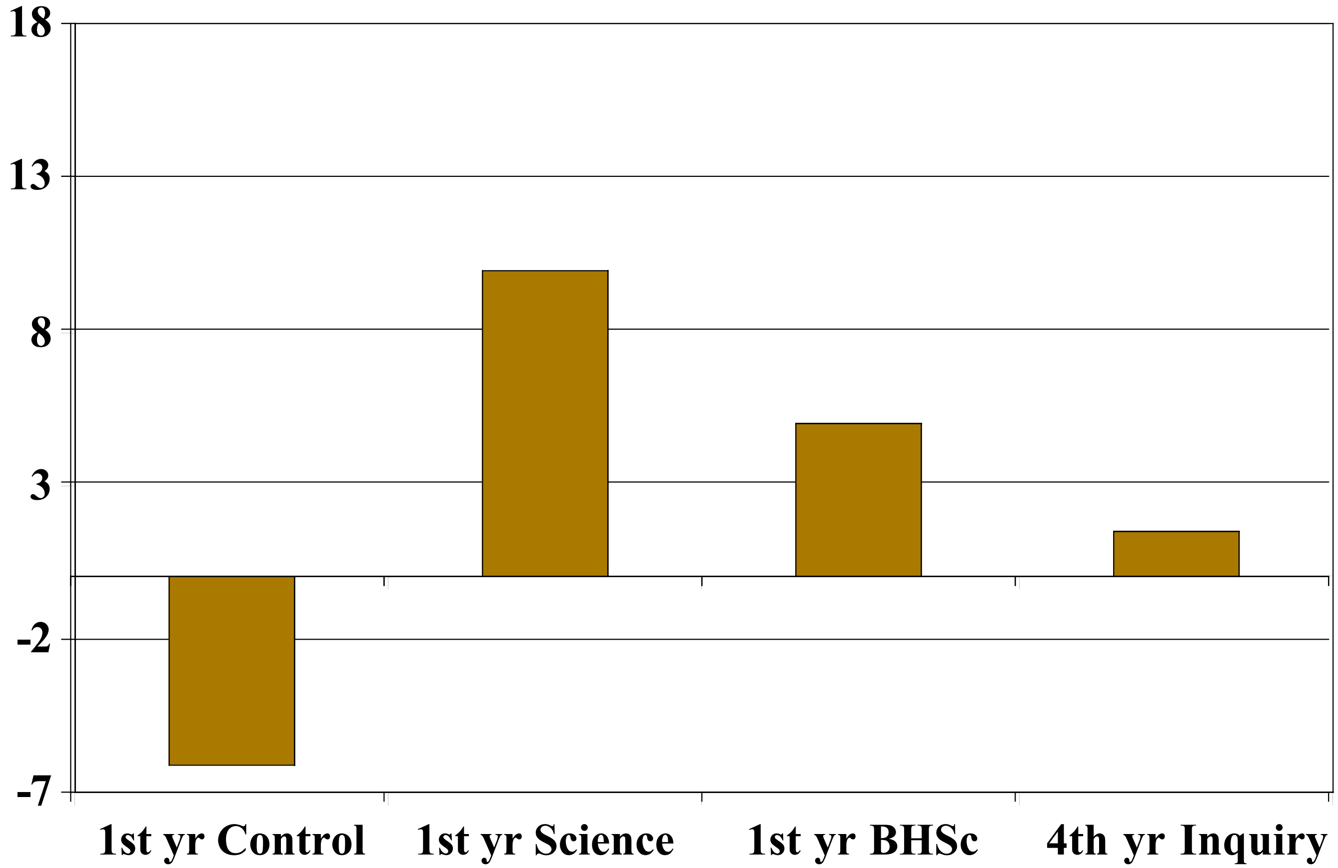
Differences in Critical Thinking Scores ($p<0.001$)



Differences in Information Seeking Scores ($p<0.001$)



Differences in Self-Assessment Scores (p<0.001)



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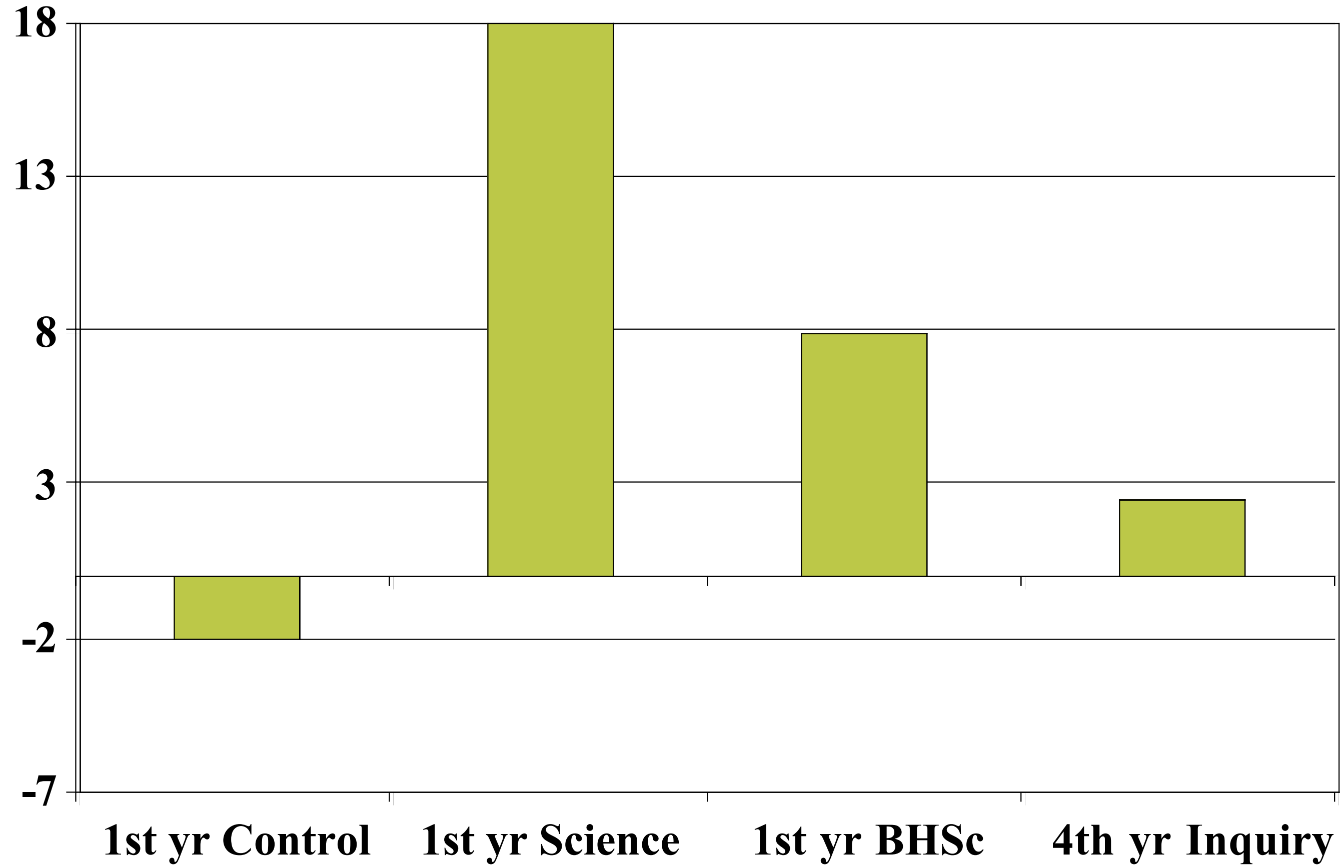
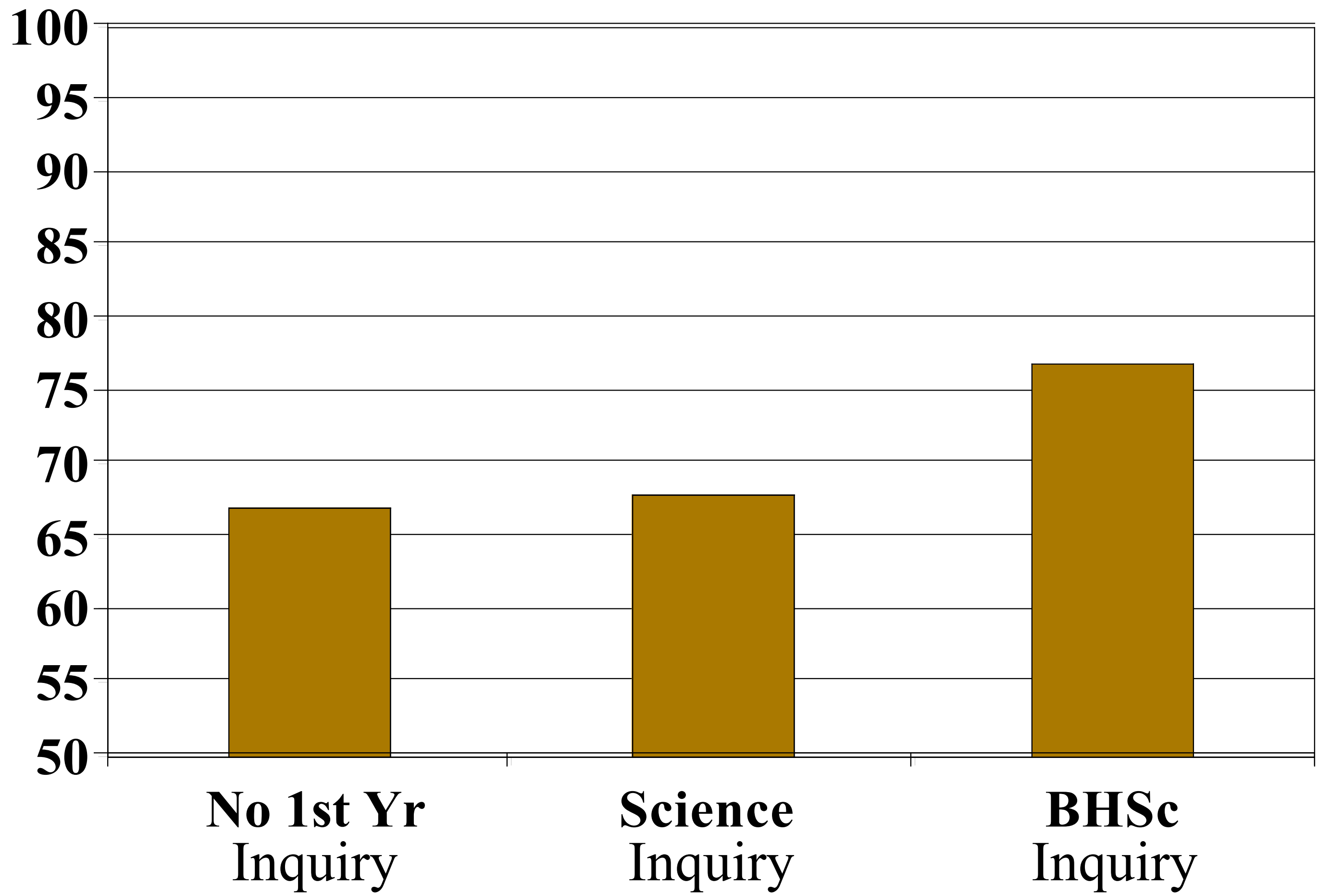


Follow-up Self-Assessment Evaluation after 3 Years



How do Students Adapt to a "No-Content" Course?

- Inquiry courses are all about Process – not Content.
  - Process of learning and finding appropriate resources.
  - Process of asking and answering questions independently.
  - Processes involved in successful group work
- Some students **love** the Inquiry process:
  - They love the freedom to explore new their own interests.
  - They love working toward goals they define themselves.
- Some students **hate** the Inquiry process:
  - They dislike lack of course structure and lack of goals.
  - They long to be told what to do and when to do it.

Conclusions re Year 1 Inquiry - 1

- Inquiry courses are labour-intensive, demanding, rewarding - and most beneficial to students.
- Inquiry courses develop life-long research and work skills that translate across boundaries.
- Students learn to think for themselves and work for themselves – often for the first time.
- Lack of structure is a benefit, not a hindrance, to learning – but it takes some adjustment.
- Inquiry does improve student performance in the short term in ways that are measurable.

Conclusions re Year 1 Inquiry - 2

- "Inquiry" skills are highly valued by employers.
- Inquiry format can be adapted to the teaching of any subject, any discipline.
- Because students learn to 'work for themselves', the role of an instructor is different in Inquiry courses.
- Laboratory activities are excellent venues for inquiry opportunities – a lab experiment ***is*** Inquiry.
- Inquiry experiences are received very favorably by students and reflect current "style of learning."

Honours Integrated Science – a New Program at McMaster

iSci @ Mac

"We should be thinking of different approaches to education that will foster interdisciplinary science and lead to students who are better able to take on the challenges of the future."

J. Ellis Bell, 2007

What is *iSci*@Mac?

- Interdisciplinary, research-based undergraduate science program.
- Inquiry-based format.
- Targeted toward highly motivated, high-achieving students (target cohort - approx. 60 students/year).
- Integrated learning of scientific knowledge and skills from multiple disciplines.
- Team teaching, innovative instructional styles.
- Hands-on lab and field-based research beginning in Level I.
- Integrated scientific literacy program.
- Collaborations with government, industry, community partners.

iSci@Mac will be Unique

- A number of universities have developed interdisciplinary, Year 1 science programs, e.g.,
  - UBC (Science 1)
  - Princeton
  - Columbia
  - Berkeley
- No follow-up program in upper years:
  - Students enter "traditional" science programs in Year 2 and continue on to graduation.
- Many students in above programs would like to have on-going interdisciplinary experience – our 4-year program will be unique in addressing this need.

Proposed iSci Program Structure

Level I	***iSci*** 24 units Integrated Science I	6 units electives
Level II	***iSci*** 18 units Integrated Science II	12 units Associated discipline courses
Level III	***iSci*** 12 units Integrated Science III	18 units Associated discipline courses
Level IV	***iSci*** 12 units Integrated Science IV	18 units Associated discipline courses

Proposed iSci Program Courses

- **Level I**

iSci I (24 units)

*i*Sci 1A24: Fully integrated math, physics, chemistry, biology, psychology, earth science, computing. Theme-based instructional modules

- **Level II**

iSci II (18 units)

*i*Sci 2A06: Integrated math/physics/chemistry course
*i*Sci 2B06: Integrated phys/bio/neuroscience course
*i*Sci 2C06: Team research, modeling, instrumentation

- **Level III**

iSci III (12 units)

*i*Sci 3A06: Data analysis, inquiry/scientific communication & leadership skills
*i*Sci 3B06: Interdisciplinary team research project

- **Level IV**

iSci IV (12 units)

*i*Sci 4A12: Interdisciplinary team research project

iSci Level I Course Map

"Imagine a university or college where students taking science classes didn't take introductory chemistry, introductory biology, introductory physics, and introductory math or computer science courses but instead took a single, truly interdisciplinary course where the chemistry, physics, biology, and math were taught in a unified context so that students could not escape from the connections between the subjects and were held responsible for the connections between them, right from the start of their college education." J. Ellis Bell – Feb. 2007

isci.xls

	A	B	C	D	E	F	G
1		mathematics-physics component			biology-chemistry component		
2	Level 1	physics	mathematics	biology		chemistry	other
3		1D + 2D kinematics	Cartesian plane				
4		Newton's laws of motion	vectors, components				
5			polar coordinates				
6			integration of polynomials				
7			tangents to curves				
8		conservation laws:	integration more generally				
9		energy (potential, kinetic)	gradients, level curves				
10		momentum	scalar and vector fields				biophysics
11			Solving multiple equations				
12			MATLAB for illustrations				
13							
14		simple harmonic motion	simple differential equations				statistics
15							
16		other harmonic motion	numerical solutions				Earth sciences
17			to nonlinear equations				
18							
19			differentials				
20							computer sciences
21					population		statistics
22							
23		general law of gravity	2- and 3-D integrals				
24		planets and orbits	numerical integration				
25		Kepler's laws					
26							
27							
28		rotational motion	2- and 3-D integrals				
29		moments of inertia					
30		angular momentum					

The second part of the course focuses on Newton's laws: the effect of forces on motion. On an elementary mathematical level, this presents an opportunity to review operations on vector spaces (ie addition of forces, decomposition in different components, etc), as well as the introduction of the sophisticated concept of a vector field: the assignment of a vector (force) to different positions in space. The statement and applications of Newton's second law provides an introduction to a simple differential equations. The rich example of a harmonic oscillator allows for the concept of general solutions to homogeneous first and second-order differential equations to be fully discussed. A damped oscillator is an ideal way to introduce particular solutions to an inhomogeneous differential equation. Several other interesting and intuitive examples can be explored at this stage, making full use of the physical intuition (pendular motion, resonances, etc) to explain mathematical properties. Conversely, general mathematical results can lead to the analysis of unexpected physical regimes that students would likely not be able to derive from intuitive reasoning alone. This last feature (the discovery of effectively new physics from the use of mathematics) can be further enhanced by concrete applications of numerical algorithms, thereby introducing students to fundamental ideas in numerical analysis (errors, stability, convergence, etc).

Benefits from *iSci@*Mac?

- High profile, ‘flagship’ program for Science.
- Program hopefully will attract top national & international students.
- Program will promote interdisciplinary collaborations & interactions among faculty and students.
- Integration strategies developed may be applied to other programs in the Faculty.
- Graduates will be highly sought after by research departments in academia, government and industry.

Moving Forward with *iSci*

- ‘Committee of Instruction’ established
  - Course and curriculum development, assessment strategies
- ‘Program Advisory Board’ to be established
  - Members of university, government, industry, community
  - To advise on curriculum, research projects, funding sources
- Preparation of materials for formal ‘Approvals’ for new program
  - University (Fall 2007) and Province of Ontario (Jan. 2008)
- Prepare materials for promotion of *i*Sci program to schools – May 2008
  - Promotion of program – 2008/09 academic year
- Admit first cohort in May 2009 for September 2009
- Seek external funding

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- And thanks to you!

Many Challenges! Even More Opportunities!

¡Sci @ Mac

"If you don't make mistakes,
you're not working on hard enough problems."

Frank Wilczek