Integration of Mathematics into Interdisciplinary Science Programs

Ana Lučić
McMaster University
Hamilton, Ontario
Student Number: 1045778
lucica@mcmaster.ca

Senior Research Project, Dept. of Mathematics and Statistics
Supervisor: Dr. Miroslav Lovrić

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1 Background and Motivation

Mathematics is the backbone of science. It provides the tools necessary to write the laws of physics, which determine the mechanisms behind intramolecular bonding, which in turn establish biological interactions of living organisms. Its applications are infinite - extending far beyond specific scientific disciplines, from modelling disease epidemics, to understanding economic theory, to monitoring the effects of climate change. It is clear that mathematics is an integral part of our world; therefore it should also be an integral part of our education.

Students in the secondary school system are taught math up until Grade 11, after which, students are able to choose whether or not they wish to continue with the subject. This indicates that a significant portion of the Canadian population has only a basic understanding of mathematics. When enrolling in post-secondary education, students are able to choose programs that do not require any math courses. Therefore, an even larger portion of the population, including those who are considered to be educated, has not been exposed to higher-level mathematical ideas. It seems promising that students who pursue a science degree at university are required to take at least some math courses. However, this is generally limited to courses at the first year level. Based on this, it is evident that even individuals who have received higher education in science do not necessarily have a firm grasp on mathematical concepts, further narrowing the portion of society that understands math.

The scientific community has reached a point where it requires a different type of scientist; one who is able to solve new world problems that extend further than just biology, chemistry or physics. This is why universities have begun implementing Integrated Science programs, which facilitate interdisciplinary learning, and emphasize highlighting connections between different scientific disciplines. One would assume that because math is such an important part of all aspects of science, programs that claim to be integrated would have a significant math requirement, but unfortunately this is not always the case. There exist programs that incorporate little to no mathematics, yet students still graduate with an Integrated Science degree. At this point, we can see that the portion of the population that has a substantial grasp on mathematics seems to be getting smaller and smaller. Individuals with high school diplomas, university degrees, university degrees in science and now even university degrees in Integrated Science do not necessarily possess a well-defined comprehension of mathematical thought. Furthermore, math is required to add a quantitative
dimension to any results; without math, all results remain qualitative. How can we train the type of scientist we need if we do not require them to understand the universal language with which scientific discoveries are substantiated? This paper seeks to investigate the optimal method behind administering an interdisciplinary education in order to breed students with a holistic understanding of science, at the root of which is mathematics.

2 Purpose

The goal of this study is to understand the benefits of interdisciplinary science programs, and to assess the delivery of mathematics in such programs in order to optimize the students’ academic experience.

This study seeks to investigate the correlation between academic success and involvement, whether it is past or present, in the Integrated Science Program (iSci) at McMaster University. It is evident that for the most part, iSci students have experienced academic success at McMaster. However, the reasoning behind this needs to be investigated; is this success solely attributed to the program itself, or are there other factors that facilitate these achievements?

This project has three components: the first is a comprehensive analysis of interdisciplinary science programs in Canada, while the other two specifically involve the iSci program at McMaster.

3 Part A: Review of Current Programs in Canada

This portion of the study examines nine different interdisciplinary science programs in Canada. It will focus on programs by splitting them into two categories: those that are fully integrated, and those that are not. Fully integrated programs, such as those at McMaster, UBC (ScienceOne), Dalhousie, and the University of Alberta, are those that combine multiple disciplines into one course. Mix-and-match programs, like those at Carleton, Concordia, UBC (Coordinated Science Program) and UNBC offer a type of custom curriculum, where the students can choose different subjects that they believe are complimentary, and combine them into one degree.
3.1 Methodology

These programs were investigated by means of literature review, as well as online research using each university’s website. It should be noted that when assessing the number of mathematics courses required by any program, statistics courses were included, but computer science courses were not.

Dr Richard Hoshino, a math professor from Quest University in British Columbia, was kind enough to answer some questions via e-mail about the integration of mathematics in the unique program at Quest. This information was combined with findings obtained from online research to compile the analysis of the Quest program.

3.2 Results

Fully Integrated Programs

<table>
<thead>
<tr>
<th>Institution</th>
<th>Intake</th>
<th>Length of Program</th>
<th># of Math Courses</th>
<th>Stats Included?</th>
<th>Comp Sci Included?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta</td>
<td>40</td>
<td>1 year</td>
<td>2</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Dalhousie</td>
<td>70-80</td>
<td>1 year</td>
<td>2</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>McMaster</td>
<td>60</td>
<td>4 years</td>
<td>3</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>UBC (ScienceOne)</td>
<td>75</td>
<td>1 year</td>
<td>2</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

University of Alberta: Science 100

The Science 100 course offered at the University of Alberta is only administered in first year, and combines biology, chemistry, computer science, earth science, mathematics, physics and psychology into one full-year course that highlights connections between all of these disciplines. It also includes a 3-unit writing course, which focuses specifically on the methods and strategies behind scientific writing. Students who enrol in Science 100 do not have the opportunity to take any electives in their first year of study, however they will have the appropriate prerequisites to enter any degree program in the science faculty in second year. In addition, Science 100 incorporates an individual research project as well as fieldwork, so students gain experience in areas where they would not necessarily be able to if they were in a regular science program.

Science 100 includes the equivalent of two first-year math courses, which is the case for most university science programs. Considering it is only a first-year program,
students who pursue a major in mathematics will have taken approximately the same
number of math courses as students who did not do Science 100.

**Dalhousie University: Integrated Science Program (DISP)**
The DISP is only administered in first year, and offers integrated classes in parallel
to regular ones. There are four options: Integrated Science, Integrated Biomedical
Science, Integrated Physical Science and Integrated Life Science. All students take
the same base courses, and then choose how much math and physics they wish to
incorporate based on these options. The process of choosing an Integrated Science
option is important because it limits what second year science programs students can
gain entry into afterwards. Dalhousie is unique in offering these different versions
of integrated science. DISP also includes the university’s writing requirement in its
curriculum.

All four options include a full year of calculus with the exception of Integrated
Life Science, which incorporates a different half-year course instead. However, stu-
dents cannot pursue a major in mathematics and/or statistics if they choose the
Integrated Life Science option in first year. All options include the same half-year
statistics course, therefore every DISP student takes at least one math course and
one statistics course. Similar to the program at the University of Alberta, because
the program is only one year long, students majoring in mathematics will have taken
approximately the same number of courses, regardless of whether they enrolled in
DISP, general science, or math in first year.

**McMaster University: Integrated Science (iSci)**
Integrated Science at McMaster is a four-year fully integrated honours program. In
first year, students take a 24-unit course consisting of biology, chemistry, earth and
environmental science, mathematics, physics and scientific literacy. In upper years,
the iSci portion of the program becomes smaller so students can fill their electives
with courses they need in order to complete their chosen concentration. Alternatively,
students can simply complete an Integrated Science degree without a concentration.
The program is designed so that after first year, students have the prerequisites
to switch into most second-year programs in the faculty of science.

In first year, iSci students are taught the equivalent of two first-year math courses.
At McMaster, first-year science students who are not in iSci must declare themselves
to be in one of the four core science programs. In Life Sciences, and Earth and Envi-
rmental Sciences, students are only required to take one math course in first year.
In Physical Sciences, students are required to take two math courses in first year, the same two that students in Integrated Science take the equivalent of. Students who apply to the Mathematics and Statistics program are required to take four math courses in first year. iSci satisfies two of the three first-year courses required for students wishing to pursue a major in Mathematics and Statistics. iSci students would have to take the third course as one of their two electives in first year. In second year, iSci students take another mathematics course, totalling to a minimum of three in order to complete the degree. Over four years, the iSci portion of the program accounts for the equivalent of 22 courses out of the 40 in an Honours degree. Because of this, iSci students specializing in mathematics (or any concentration for that matter) are unable to declare a major.

University of British Columbia: ScienceOne
The ScienceOne program is the oldest integrated science program in Canada. It is only administered in first year, and it consists of one 25-credit course, including lectures, tutorials, labs, and independent research projects. The program integrates biology, chemistry, mathematics and physics, and has two professors teaching each discipline. ScienceOne also focuses on small group activities, allowing the students to bond with one another while receiving additional support and guidance from professors. The ScienceOne instructors make a specific point to rarely include multiple-choice questions, but rather reasoning problems, essay questions and representation-translation problems. This allows instructors to ask questions incorporating multiple disciplines at the same time. The program is known for being more difficult than standard first-year science programs, but it has been shown that ScienceOne students have greater academic success in upper year university courses.

The mathematics component of ScienceOne includes the equivalent of two first-year math courses, specifically Differential Calculus and Integral Calculus. Students who have initially declared their major as mathematics are also required to take two math courses in first year, along with one physics course and one computer science course. Regular science students are only required to take one math course in first year. Since each ScienceOne student receives a custom program designed for them by a faculty administrator, the amount of math courses varies based on the student’s interests.
Mix-and-Match Programs

<table>
<thead>
<tr>
<th>Institution</th>
<th>Intake</th>
<th>Length of Program</th>
<th># of Math Courses</th>
<th>Stats Included?</th>
<th>Comp Sci Included?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carleton</td>
<td>No cap</td>
<td>3 or 4 years</td>
<td>2</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Concordia</td>
<td>10-15</td>
<td>3 or 4 years</td>
<td>0</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Quest</td>
<td>180</td>
<td>4 years</td>
<td>1</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>UBC</td>
<td>168</td>
<td>1 year</td>
<td>2</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>UNBC</td>
<td>No cap</td>
<td>4 years</td>
<td>0</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Carleton University: Integrated Science Institute (ISI)**

The ISI at Carleton opts to combine the fundamental aspects of science into a more practical degree, which is designed for students who wish to enter the workplace upon graduating, as opposed to continuing with academia. ISI students have the option of completing the program in 3 or 4 years (BSc vs. HBSc). There are nine concentration options, including Life and Health Sciences, Science Education, Forensic Science, Science and Policy, Science and Ethics, Science and The Arts, Information Science and Information Technology.

All ISI students are required to take two math courses in first year: This is the only program that has a mandatory first-year linear algebra course included. The Information Science and Information Technology concentrations are the only ones that require additional math courses. These concentrations also require one statistics course, along with the Science and Policy, and Science and Ethics concentrations. The Forensic Science concentration requires two statistics courses, but the other four concentrations do not require any mathematics (past first year) or statistics.

**Concordia University: Science College**

The Science College at Concordia has the smallest intake of all the programs listed, which facilitates very personal relationships between faculty and students. The program requires students to choose a major in science, then complete a minor in multidisciplinary studies. The courses offered to complete this minor are either historical, involve current issues or are self-directed, and vary from year to year. Examples of previous courses offered include Historical, Philosophical and Social Aspects of Science, and Current Issues in Physical, Biological and Mathematical Science. These courses challenge students to make connections between disciplines, and identify possible future directions for research based on their findings.
There are no mathematics courses listed in the degree requirements for the Science College. If students choose to pursue a major in math, they would need to complete the same number of courses as any other student at Concordia.

**Quest University: Block Program**  
Quest is a private liberal arts university in Squamish, British Columbia that offers one degree: a Bachelor of Arts and Science. All first year undergraduates are enrolled in the same classes at the same time in order to form a sense of cohesion and community among students. Quest implements a block program over the course of four years, consisting of 32 blocks total. Each block is approximately three and a half weeks long, and they are completed one at a time. The first two years of the program are referred to as the Foundation Program, which contain all aspects of arts and science. The last two years make up the Concentration Program, which allows students to specialize in a custom way.

Because of the way Quest is set up, there are no predetermined majors. The final block of Foundation Program is called the Question, where each student chooses a specific topic that they wish to investigate, then meets with a faculty mentor in order to choose appropriate courses for the Concentration Program that will facilitate answering their Question.

Quest only requires one math course during the Foundation Program, and gives its students seven different options, including problem solving, history, modelling and finance. Since each student’s academic path is unique, the number of required math courses is completely dependent on how relevant mathematics is to each student’s Question. The Cornerstone block, which is the first course in the Foundation Program, involves one full day of math, where students learn proof by contradiction, deductive reasoning, and how to think logically.

Statistics I is by far the most popular mathematics course; approximately 30% of students use some form of statistics in answering their Question. In the Foundation Program, the most popular math course for students who enjoy the subject is Spherical Trigonometry, while the most popular for students who do not have a natural aptitude for math is Mathematical Problem Solving. A math-based Question would entail the completion of about 12 math courses; approximately 5% of students choose to pursue this. Examples of Questions involving math are “How can we optimize the efficiency of a system?”, “How can we produce economic-environmental win-wins?”, and “How can mathematics inspire progress?”. One student in particu-
lar designed an alternative university course registration system as their final project, and this has actually been implemented at Quest. This student’s paper was recently accepted into the world’s most prestigious Artificial Intelligence conference.

University of British Columbia: Coordinated Science Program (CSP)
The Coordinated Science Program (CSP) at UBC is more of a support group rather than an integrated program. In first year, CSP students enrol in all of the same courses as regular science students, but they are all in the same lectures, facilitating a sense of community and belonging. In addition, there is a weekly CSP workshop where relationships between scientific disciplines are established and connections are made. There are approximately 30 students in each workshop. Like ScienceOne at UBC, this is also only a first-year program.

CSP students are only required to take two first-year math courses, like every other science student at UBC. The main difference is that CSP students take these courses with each other.

University of Northen British Columbia (UNBC): Integrated Science
The Integrated Science program at UNBC offers a basic foundation of mathematics, chemistry, biology and physics. Each student has the same requirements in first and second year, then chooses two concentrations for the upper years of their degree. Students must complete at least six courses in each concentration, and at least 15 courses total must be third- or fourth-year credits. Concentrations include Biology Ecology Biochemistry and Molecular Biology, Chemistry Biochemistry and Molecular Biology, Computer Science, Environmental and Earth Science, Geography Science and GIS, Mathematics and Statistics, Natural Resources and Forestry, and Physics. Each course can only be used as credit in one of the two concentrations. A unique aspect of this program is that students are able to switch into as well as out of it.

In first and second year, students have the option of taking mathematics, both mathematics and physics, or just physics. This allows students to choose how much math they would like to take, if any at all, based on their preferences and abilities. In theory, a student could complete an Integrated Science degree at UNBC without taking any math courses. If students choose Mathematics and Statistics as one of their concentrations, any upper year math courses, with the exception of biostatistics, can be used to satisfy the concentration requirements.
3.3 Discussion and Analysis

Fully Integrated Programs

It is evident that the all of the fully integrated programs have a small class size. These are elite programs, which accept only high-achieving high school students. These are also all Honours programs. These programs are either implemented only for the first year of study, or for all four years of an undergraduate degree.

The programs at the University of Alberta, Dalhousie and UBC (ScienceOne) require students to take the equivalent of two math courses. Since these programs are only for first year, two math courses seems appropriate considering students must also learn about other scientific disciplines.

iSci at McMaster is the only four-year fully integrated program, and it requires students to take the equivalent of three math courses over the course of four years. The issue with this is that these students graduate with an “Honours Integrated Science” degree, as opposed to students at Quest who obtain an “Arts and Science” degree, and students at Alberta, Dalhousie and UBC whose degrees are representative of whichever major they choose after first year. The question that arises is does a degree deserve the name “Integrated Science” if only three math classes are required to complete it. In addition, mathematics is not actually integrated into the program in second year; it is the only discipline that does not have a component in the projects, and as a result is taught separately.

It should be mentioned that if a student chooses to pursue the Integrated Science option at Dalhousie, as opposed to the Integrated Biomedical Science, Integrated Physical Science, or Integrated Life Science alternatives, two math courses are required along with a course in statistics, totalling three required courses.

Of all the programs, regardless of whether they are considered to be fully integrated or not, Science 100 at the University of Alberta is the only program that entails computer science, and the Dalhousie Integrated Science Program is the only one that requires students to learn statistics.

Mix-and-Match Programs

Although it seems as though the Science College at Concordia is the only program with a small class size, both the Coordinated Science Program at UBC and the block
program at Quest divides the total intake into groups of 25-30 students per class. All three of these programs are elite. Like its sister program, ScienceOne, the CSP at UBC is only administered in the first year of study, while the rest are full-degree programs.

The CSP requires students to take two math courses in the first year of study. Again, since this is only a first-year program, mathematics is represented as equally as the other disciplines.

Carleton’s ISI program requires students to take two math courses over the course of three to four years, depending on whether or not they choose to pursue an Honours degree. The programs at Concordia and UNBC do not require students to take any mathematics courses. Similarly to the McMaster program, this poses an issue because the students are graduating with “Integrated Science” degrees, when in fact, they have learned little to no mathematics. The math courses required by Carleton are basic first-year courses, and therefore do not emphasize key mathematical concepts such as critical thinking and logical reasoning. The programs at Concordia and UNBC do not require any mathematics courses at all, which also makes claiming that these programs are integrated seem unreasonable.

Quest University requires students to take one math course throughout their undergraduate career. However these students must take courses across all disciplines, including the arts, so requiring students to take more than one course in mathematics seems unrealistic. The Foundation Program is composed of six science blocks and seven arts blocks, in addition to unique inquiry courses such as Cornerstone, Rhetoric, and Question. Of the six science courses, two are physical science, three are life science, and one is mathematics, so it seems as though math has a fair representation in comparison to the other science disciplines in the Foundation Program. The number of mathematics blocks included in the Concentration Program is completely dependent on what each student’s individual Question is. There are nine upper year math blocks to choose from, including Discrete Mathematics, Differential Equations, Multivariable Calculus, Real Analysis and Abstract Algebra. There are also two statistics courses offered.

The block program at Quest is different from the others because it involves both the arts and sciences. Although students are not required to enrol in more than one mathematics course, the math they do take is valuable. Rather than simply learning formulae and algorithmic methods of problem solving, students learn key
mathematical concepts that can apply to many other aspects. Since Quest is a liberal arts university, it cannot be expected that every student will have an interest in mathematics, therefore allowing students to choose from a variety of courses allows for more relevant and effective learning. In theory, the program that Quest offers is the ideal way to have an integrated education, the issue is that it would be difficult to implement on a larger scale.

4 Part B: Survey of Current iSci Students

This is one of two segments that will deal specifically with the Integrated Science program at McMaster. The main focus of this section will be a survey of current students enrolled in the program. This will help us understand the general mentality and perceptions of iSci students, and we can use these findings to assess how the program has contributed to the academic success of its students.

4.1 Methodology

Participant Recruitment

The total population consisted of 43 students currently enrolled in the iSci program at McMaster University. There were some participants who did not complete the survey, resulting in a smaller sample size for some of the questions. Participants were recruited through an e-mail which was sent to all Integrated Science students through the administration’s mailing lists.

Data Collection

The survey was administered online through LimeSurvey, which is open source survey software recommended by the McMaster Research Ethics Board (MREB). The data was collected in March of 2014; therefore every participant had been in the program for (at least) almost one full academic year. The survey was completely anonymous; it did not ask for a name or gender, as each survey was only marked with the IP address of the computer it was completed with. The only required participant characteristic was that they were enrolled in the Integrated Science program at McMaster University, and so were likely be between the ages of 18 and 22. Participants were asked to give their current year of study. No other demographic information was used.
Ethics

This survey was approved by the MREB. Participants were able to withdraw at any point by simply exiting the survey, with no consequence. Participants also had the option to skip any question they did not feel comfortable answering. Potential ethical concerns include the fact in 2010, I was a part of the iSci program at McMaster, and therefore know students who were in the program in the 2010/2011 academic year personally. Dr. Lovric, the faculty supervisor, taught in the iSci program from 2009 to 2013, therefore the majority of students participating in the study have had him as an instructor at some point. The anonymity of the survey was what minimized this conflict of interest.

Analysis Methods

Ranking scoring: When participants were asked to rank different options, each time an option was ranked first, five (5) points were allocated to that option. Each time an option was ranked second, four (4) points were allocated to that option, and so on. The summation of scores for each option was then computed to produce the overall rankings. Therefore, the option with the highest score had the highest overall ranking.

Pointed statement scoring: In one particular question, participants were asked if there was too much of a certain discipline involved in the program, too little of each discipline, or just enough. Each time a participant said there was way too much, or somewhat too much of a certain discipline, the scoring assigned was +1. Each time a participant said there was way too little, or somewhat too little of a certain discipline, the scoring assigned was -1. A score of 0 was assigned when participants said there was just enough of a certain discipline. The summation of these scores was used to produce the overall score. To further clarify, this implies that in this particular study, if every participant claimed there was too much of a subject, the score for that subject would be +43. If every participant claimed there was too little of a subject incorporated, the score for that subject would be -43. If every participant said there was just enough of a certain discipline, the score for that subject would be 0. This scoring was not used for all pointed statements, only when relevant.
4.2 Results

Q1. *What year are you in?*
The majority of participants who took part in this survey were in their second year of study. The full results are listed below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>23.81%</td>
</tr>
<tr>
<td>Second</td>
<td>33.33%</td>
</tr>
<tr>
<td>Third</td>
<td>26.19%</td>
</tr>
<tr>
<td>Fourth</td>
<td>11.90%</td>
</tr>
</tbody>
</table>

Q2. *Please rank your favourite science subjects.*

<table>
<thead>
<tr>
<th>Subject</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>133</td>
</tr>
<tr>
<td>Chemistry</td>
<td>120</td>
</tr>
<tr>
<td>Earth and Environmental Science</td>
<td>103</td>
</tr>
<tr>
<td>Mathematics</td>
<td>127</td>
</tr>
<tr>
<td>Physics</td>
<td>117</td>
</tr>
</tbody>
</table>

Here, a higher score indicates a higher ranking. Therefore, biology is the most well liked subject, followed by mathematics, chemistry, physics and then earth and environmental science.

Q3. *The amount of __________ integrated into the program is too much, too little or just enough.*

<table>
<thead>
<tr>
<th>Subject</th>
<th>Just Enough</th>
<th>Too Much/Too Little</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td>Chemistry</td>
<td>27</td>
<td>-7</td>
</tr>
<tr>
<td>Earth and Environmental Science</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Mathematics</td>
<td>15</td>
<td>-21</td>
</tr>
<tr>
<td>Physics</td>
<td>11</td>
<td>-19</td>
</tr>
</tbody>
</table>

It is evident that students feel as though there is not nearly enough mathematics or physics incorporated into the program. It should also be noted that these were two of three subjects where no participant felt that there was way too much.
Q4a. *Agree or Disagree: The program would benefit from the inclusion of Computer Science.*

71.43% of participants stated that the iSci program would benefit from the inclusion of computer programming. It should be noted that in the 2010/2011 year, ISCI 1A24 served as an appropriate prerequisite for any course that required COMP SCI 1MD3, but this is no longer the case.

![Figure 1: Participant Responses to Q4a](image)

Q4b. *Agree or Disagree: The program would benefit from the inclusion of Statistical Methods.*

80.95% of participants stated that the iSci program would benefit from the inclusion of Statistical Methods. It should be noted that although some concepts from statistics are included in the second year of the program, the amount is not equivalent to a full course in statistics.

![Figure 2: Participant Responses to Q4b](image)
Q5. Do you believe math is important as an integral part of interdisciplinary studies? Why or why not?

All participants that answered this question felt that math was important with regards to integrating scientific disciplines. There were two participants who did not provide a response. Furthermore, many of the participants gave answers indicating they thought mathematics was imperative in interdisciplinary studies; some of the answers are listed below. Common themes that resonated among responses were that math is the foundation for science, and that understanding the math behind statistical analysis is important.

The following three quotations mention the importance of math as a universal language with which we can quantify all scientific findings, regardless of the discipline.

“Math is how science is quantitatively expressed. It is important to these interdisciplinary studies because it allows us the freedom to integrate concepts... Math gives us a language in which we can speak about the concepts in our work without confining us to any one discipline.”

“It’s an incredibly important part. Math is both its own discipline and a tool for other disciplines. How can you do real authentic science if you don’t understand how math and stats work?”

“Yes. All disciplines require a comprehensive understanding of mathematics in order to maximize their utility. I would suggest increasing the mathematical focus of the Integrated Science program.”

Both of the following quotations reference the notion of including computer programming in the iSci program. The first goes on to extend this to statistics as well.

“It’s the underlying tool for all studies. I find it important to some studies more than others though. I think statistics and programming are a common ground in all disciplines. Good understanding of data fitting, causality, correlation are important...”

“Absolutely, understanding most scientific models implicitly means also understanding the mathematics that researchers use to support these models. There are also the extra skills related to good math education, especially understanding logic. This is also addressed with the much needed addition of programming.”

These final three quotations from participants all deal with the common theme of the skills that mathematical problem solving teaches students. The final quotation encompasses this idea exactly.
“Yes, math is a very important part of the interdisciplinary studies because studying math trains students to think rationally and logically when approaching problems... Math is the "glue" that allows an interdisciplinary point-of-view.”

“In my brief two years of my undergrad so far, math has been a constant area of struggle for me, but also an area that is much needed in all other aspects of science. Varying from statistics to multivariable calculus, it is extremely necessary and I wish that we had more time to learn it in a greater depth or practice it more thoroughly.”

“I think math is extremely important because it is a ubiquitous tool in all scientific disciplines. Not everything in math class necessarily becomes useful later on, but every science requires some mathematical understanding.”

**Q6. Please choose your three favourite aspects of the iSci program.**

<table>
<thead>
<tr>
<th>Answer</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Having iCons instead of traditional lectures</td>
<td>16.67%</td>
</tr>
<tr>
<td>Independent research</td>
<td>38.10%</td>
</tr>
<tr>
<td>Integration between disciplines</td>
<td>40.48%</td>
</tr>
<tr>
<td>Integration of course content into projects</td>
<td>26.19%</td>
</tr>
<tr>
<td>Interactions with peers</td>
<td>42.86%</td>
</tr>
<tr>
<td>Interactions with professors</td>
<td>57.14%</td>
</tr>
<tr>
<td>Prevalence of group work</td>
<td>16.67%</td>
</tr>
<tr>
<td>Scientific Literacy Classes</td>
<td>9.52%</td>
</tr>
<tr>
<td>Small class sizes</td>
<td>52.38%</td>
</tr>
</tbody>
</table>

It is evident that of these nine options, the most popular choices are all related to small class sizes. The ability to interact on a personal level with both professors and peers stems from the fact that there is a maximum of 60 students admitted to the program each year, and usually an even small number in the classroom at a given time.

Integration between disciplines and independent research are the fourth and fifth most popular options, which indicates that participants enjoy making connections between different areas of science in their own ways. These are both idealistic aspects of the program.

The four least popular options are all logistic aspects of the program, which indicates that although students enjoy iSci classes more than traditional classes (refer to Q9a), it is not necessarily because of the classes themselves.
Q7. What do you wish to take away from a degree in Integrated Science?
In general, participants expressed an interest in obtaining a well-rounded education that would provide the necessary preparation for either further studies in academia or employment. Another common factor was the desire to learn about connections between different scientific disciplines, and how to communicate these findings effectively. Some of the responses are listed below.

“I would like to be able to obtain the skills needed to independently research topics that incorporate more than one science as most real world problems aren’t confined to one discipline.”

“I wish to be able to understand scientific ideas in any discipline, and to be well prepared for a scientifically-focused career/further scientific education in whatever field I ultimately choose.”

“A more holistic understanding of basic scientific concepts, an ability to think critically and self-direct my learning, and most importantly the skills needed to successfully communicate scientific ideas.”

“I intended to take away the knowledge with which I could approach research topics broadly, steadily narrowing down into the best possible answer from all sides.”

“I aim to be more skeptical and logical in daily life, questioning things I may have previously taken at face value and investigating the actual processes in question to properly understand them.”

Q8. What was your admission average for iSci?
Approximately 81% of participants had an admission average of 90% or higher. No participants had an admission average lower than 86%, which indicates that these students have performed well academically in high school. Furthermore, iSci has Advanced Functions, Calculus and Vectors, English, as well as two of Grade 12 Physics, Biology or Chemistry listed as requirements for admission into the program, which indicates that the marks from these five courses must be used when calculating the admission average. Therefore, all of the participants must have excelled in science and math courses prior to university.

Q9a. Agree or disagree: I enjoy iSci classes more than traditional classes.
The majority of participants, 73.81%, agreed or strongly agreed with the above statement. 19.05% of participants had neutral feelings, and 7.14% disagreed. It is important to note that when students were asked what their three favourite aspects
of the program were (refer to Q6), having iConS (Integrative Concept Seminars) was one of the least popular choices, along with other logistic aspects of the program. This implies that although students seem to enjoy iSci classes more, it is not necessarily because of the classes themselves.

**Q9b.** *Agree or disagree: I get better grades in iSci classes than in traditional classes.* 59.52% of participants agreed or strongly agreed with the above statement. 26.19% of participants had neutral feelings, while 14.29% disagreed.
Q9c. Agree or disagree: I learn more in iSci classes than in traditional classes. 42.86% of participants agreed or strongly agreed with the above statement. 33.33% of participants had neutral feelings, while 23.81% disagreed or strongly disagreed.

Figure 5: Participant Responses for Q9c

Q9d. Agree or disagree: I prefer group work to individual work. 40.48% of participants had neutral feelings about the above statement. 38.09% agreed or strongly agreed, while 21.43% disagreed.

Figure 6: Participant Responses for Q9d

Q9e. Agree or disagree: I prefer smaller class sizes. 78.57% of participants strongly agreed with the above statements. 16.67% somewhat agreed, while 4.76% had neutral feelings. This could be one of the reasons why
students enjoy iSci classes more than regular classes. Small class sizes facilitate close relationships with professors and peers, and induce a more efficient learning environment.

Figure 7: Participant Responses for Q9e

Q10a. *Agree or disagree: I have a natural aptitude for science.*
76.19% of participants agreed or strongly agreed with the above statement, while 23.81% had neutral feelings. No participants disagreed. This implies that students would be relatively successful in the program, considering they have the predisposition to do well in science courses.

Figure 8: Participant Responses for Q10a
Q10b. Agree or disagree: *I am happy with my academic experience in the program.* 76.19% participants agreed or strongly agreed with the above statement, while 11.90% disagreed.

![Figure 9: Participant Responses for Q10b](image)

Q10c. Agree or disagree: *I am happy with my social experience in the program.* 73.81% of participants agreed or strongly agreed with this statement, while 11.90% disagreed. This may be another contributing factor to the reasoning behind why students enjoy iSci classes more than regular classes. The social experience of being in a small class is an important factor to consider.

![Figure 10: Participant Responses for Q10c](image)

Q10d. Agree or disagree: *There is a sense of belonging in the program.* 64.29% of participants strongly agreed with this statement, while only 4.76% disagreed.

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Q10e. *Agree or disagree: I have enough time for extracurricular/social activities.*

50% of participants disagreed or strongly disagreed with this statement, while 38.09% agreed or strongly agreed.

4.3 Discussion and Analysis

Overall, it seems that students in the iSci program at McMaster are happy with their experiences. The majority of students enjoy iSci classes more than traditional classes, get better grades in these classes, and feel that they learn more. However, based on our findings, it is evident that this cannot be solely attributed to the classes themselves.
It is apparent that enjoyment of classes could be considered as a contributing factor to academic success, and the social experience of small class sizes is an important factor to consider. The fact that an overwhelming majority of the study participants felt that there is a sense of belonging among students in the program attests to this idea of small class sizes facilitating personal relationships among peers, which could be one of the reasons students enjoy these classes more. When students were asked what their favourite aspects of the program were, the three most popular choices were all related to small class sizes, further indicating that they have a great impact on success and enjoyment of students in the program. In addition, the majority of students felt that they had a natural aptitude for science. This was supplemented by students’ very high admission averages, implicating their excellent academic performance in science subjects during secondary school. As a result, it is most likely that students in the program excel due to a combination of small class sizes and natural aptitude.

It is obvious that mathematics is severely underrepresented in the program. Considering its importance, it is clear there needs to be more of an emphasis on the subject. Furthermore, all participants of the study agreed with the notion that mathematics is essential in interdisciplinary studies. It forms the fundamental backbone for all scientific disciplines, along with teaching students logical reasoning and critical thinking skills, which are applicable in all aspects of science.

According to the study, students felt that the program would benefit from the inclusion of both computer programming and statistical methods. Like math, developing algorithms while programming teaches students to think logically, while statistics is the means by which scientific findings are quantified.

5 Part C: Survey of Former iSci Students

5.1 Methodology

Participant Recruitment

The total population consists of 6 former students of the iSci program at McMaster University. Participants were recruited with an informal e-mail containing a brief introduction to the study along with the survey itself. This survey was not anonymous to the investigator, but quotations were carefully chosen in order to preserve the anonymity of participants.
Data Collection
All data was collected via e-mail and stored on a password-protected computer.

Ethics
Some of the questions asked in this survey were more sensitive. This is because I knew the participants on a personal level, and knew they would feel comfortable enough to let me know if there was any question they did not wish to answer.

Bias
All of the participants were in the 2010-2011 cohort of the program, which is the second year it was run. All but one of the participants left the program after first year; therefore the majority of these responses were based on experiences that occurred over the course of that particular academic year.

Analysis Methods
Due to the small sample size, only qualitative statements were used for analysis.

5.2 Results
Q1. What program are you in now?
All but one of the participants are still completing degrees in the science field, so it is clear, for the most part, that the subject matter itself is not what deterred students from staying in the iSci program.

- Doctorate of Veterinary Medicine
- Honours Biochemistry
- Honours Chemistry
- Honours Health Studies
- Honours Life Science
- Honours Physics Co-op
Q2. How do you think you would have done had you begun in a regular science program?
All participants said they felt they would have done very well in a regular science program. All but one participant said they felt as though they would have gotten better grades if they were not in iSci; Participant 2 said his/her grades would most likely have been the same.

It should be noted that both Participants 1 and 4 stated that part of the reason they felt their marks would have been higher outside of the program is due to the stress and anxiety associate with the heavy workload in iSci. These participants both felt that one of McMaster’s regular first-year science programs would have allowed them to have time for extra-curricular activities, and a more balanced life in general.

Participant 1 also noted,

“...the workload and evaluation methods of regular science programs are more reasonable in comparison to level I of the iSci program”.

Q3. Would you say you have a natural aptitude for math and/or science?
All participants believe they have a natural aptitude for both math and science.

Q4. How are your grades now?
Five of the six participants currently have A- or A cumulative averages. One participant has a B+ cumulative average.

Q5. Do you feel the program was truly integrated?
This question was met with several differing opinions; Participants 1 and 6 did not think the program was integrated whatsoever, Participant 3 felt as though it was, and the opinions of the other participants were somewhere in-between.

Participant 5 stated,

“The projects allowed us to see the involvement of each discipline in the same scientific endeavour. However, when it came down to pulling the project together, each group member ended up focusing on only one discipline as their portion of the project anyway. The resulting effect of this was that students would choose their strongest discipline as their portion of each project, and never complete work for other disciplines. Participants 2 and 4 shared the same feelings about the projects.”

Participant 2 noted,
“If it had been truly integrated, then every class that we had would have been interdisciplinary, rather than each class’ content being within a specific subject. However, we didn’t have any professors that would be able to teach a fully interdisciplinary class, because that doesn’t really exist. Profs are trained in discrete subject areas and therefore are only able to teach that subject. Since there are no interdisciplinary profs, there is no interdisciplinary iSci. This outlook that implies a truly integrated program is almost impossible.”

However, Participant 2 also noted that some subjects are inherently integrated, so the program can be seen as interdisciplinary based on the integration of its component subjects.

Q6. What impact do you think the small class size had on your academic performance? All participants felt as though a smaller class size contributed positively towards their academic success. Participant 5 stated that this was

“... not because of the reduced instructor to student ratio, but rather the way that the small class size facilitated building relationships. This allowed us to work together better to understand content. The presence of these relationships in a large setting would likely have had the same effect.”

Participant 1 echoed this view.

Q7. How did you feel about the program as a whole?
Participants 2, 3 and 6 all said that the program was a great idea, but were unhappy with the method by which it was delivered.

Participants 2 and 5 both acknowledged they learned several things in the iSci program that they would not have learned in other first year science programs, such as scientific writing and presentation skills. However, both of these participants felt that the workload was overwhelming.

Participants 5 noted that the program only entailed “surface concepts” of each scientific discipline, and felt that in upper years, this lack of depth in each subject would hinder his/her ability to advance in a specific field in science. Participant 5 also stated,

“... it [the program] is not feasible in a four year degree format... I believe this approach is better suited as a first-year program before specialization (as many of the students who switched out did).”

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Q8. Why did you choose iSci in the first place?
Four of the participants said they liked the idea of a prestigious program, and that this was one of the main factors contributing to their decision to enrol in iSci. Participant 6 stated that the opportunity of an elite program could not be turned away since the participant had worked hard for their outstanding grades in secondary school.

Participants 1, 2 and 3 all included small class sizes as being one of the attractive components of the program, along with being able to integrate across multiple disciplines in order to receive a more well-rounded education.

Q9. Were your course timetables reasonable?
Five of the participants did not feel the course timetables were reasonable.

Participant 4 stated,
“No. We had more hours of class per week than the engineers who were receiving more credits for their work than us. You never knew what class you had until you showed up (the whole schedule just said iSci). It limited the electives you could take and didn’t allow time to learn, do readings or work on projects.”

Participant 1 stated,
“No. I never had enough time outside of class to work on additional homework or to learn course content, only to work on course assignments or major projects. Not only did I have a hard time working on homework for the program, I also found it difficult to maintain a healthy lifestyle, through exercise and eating healthy, because I always found myself in a rush. It was also challenging to maintain relationships with my peers outside of the iSci program because of the busy class schedule.”

Q10. Is there a sense of belonging in the program?
Participants 3, 5, and 6 thought there was some sense of community within the program, but felt as though there were “cliques”.

Participant 5 stated,
“There was a sense of belonging for those that have found a way to belong”

This indicates that not necessarily everyone in the program felt included.
Q11. Why did you leave the program?
Two of the participants left the program because it compromised the academic path they had intended for themselves. Specifically, one of these participants would not have been admitted to Veterinary College if he/she had continued in the program.

Participant 5 felt that the mathematics and physics components of the course were delivered inadequately, and did not feel confident in his/her ability to continue in these disciplines in upper years.

Participants 3 and 6 wished to pursue certain disciplines more in-depth, and did not wish to spend time on subjects they had little interest in.

Q12. Is there anything you miss about the program?
Participants 3 and 6 said they did not miss anything about the program.

Participant 2 missed the pride of being in an elite program, and the forced challenge it entailed, as opposed to option challenge of more electives.

Participants 1, 4 and 5 stated that the main thing they missed was having all their classes with their close friends. Participant 5 went on to say that the personalized attention from professors was another aspect that has not been present in his/her current program.

5.3 Discussion and Analysis
It is to be expected that all participants have a natural aptitude for science, given the high average required for admission to the program. Furthermore, the majority of participants have continued to pursue degrees within science, and all have relatively high cumulative averages, indicating that these are all high-achieving students.

The main reasons given by participants for leaving the iSci program are all related to logistic aspects. This is essentially a combination of too much coursework, prerequisite issues, and lack of comprehensive integration between disciplines. Furthermore, inadequate delivery of certain disciplines, mathematics in particular, made some of the participants concerned about their ability to continue in those subjects, resulting in apprehensive feelings about staying in the program. However, some of the participants simply no longer wished to pursue an integrated education, and decided to focus their academic path in one particular subject area.
Some participants referenced the positive effect of working relationships with peers in the program, further indicating that small class sizes were extremely beneficial to these students. Participants also stated that these relationships were one of the main things they missed about the program, along with personalized attention from professors. Furthermore, the fact that the friends of students who left iSci also left the program attests to the effects of the social aspect. Although this simply may be an adverse effect, it supplements the notion of a sense of belonging among students in the program.

6 Conclusion

6.1 Interdisciplinary Programs in General

Overall, it seems as though the best way to facilitate an interdisciplinary education is to implement a fully integrated, one-year program. The programs at the University of Alberta, Dalhousie and UBC all include adequate amounts of each scientific discipline, including mathematics. Since these programs are only for first year, students can reap the benefits of smaller class sizes initially while still focusing their education in a specific area later on. This also allows students to form relationships with their peers as well as professors without potentially compromising the remainder of their university experience.

Although mix-and-match programs offer students many options and are quite feasible administratively, they result in more of a custom education, rather than an integrated one.

Integrating disciplines is a unique approach to science education, and it is an innovative way for interested students to highlight connections between subjects. However, programs that fail to include mathematics should not be considered “Integrated Science” programs, as math is the backbone of all sciences, and if anything, it should be emphasized.

6.2 iSci at McMaster

With regards to the Integrated Science program at McMaster, the main conclusions are that programming and statistics should be included, that a greater emphasis on math is required, and that small class sizes have a significant impact on the
program. The effect of personalized relationships with professors as well as peers has a considerable positive effect on academic success, and this is one of the most important aspects of the program.

6.3 Importance of Math

Given its importance, mathematics must be a central aspect in any Integrated Science degree. Although the specific concepts taught in math class may not be applicable to all scientific disciplines, the skills acquired from learning to problem solve are. It is important to realize that scientific disciplines are all connected, but they are on different planes of information. The rules of mathematics govern the laws of physics; these laws dictate the chemical properties and interactions of molecules, which in turn determine the biological aspects of life. Mathematics is at the root of all science, and therefore should be considered as the most important scientific discipline.

7 Acknowledgements

Thank you to the Department of Mathematics and Statistics at McMaster University for the opportunity to do this project. Specifically, I’d like to thank my supervisor Dr. Miroslav Lovrić, whose unconditional support has had a significant impact on my academic career. Additionally, I would like to thank Dr. Andrew Nicas, Dr. Manfred Kolster, Dr. Matt Valeriote, Dr. Maung Min-oo, Dr. Stan Alama, and Dr. Traian Pirvu for their contributions to my education, which further fuelled my interest and admiration of mathematics.

Thank you to Dr. Richard Hoshino for taking the time to answer questions about the program at Quest University.

Thank you to all of the students who participated in this study; these responses have been absolutely imperative in the completion of this project.

Finally, I’d like to thank my parents, Vesna and Tihomir Lučić, for the many sacrifices they’ve made on my behalf, and constant support they’ve given me in all of my endeavours.
8 References


9 Appendicies

9.1 Email Recruitment Script for Part B

Miroslav Lovric
Professor of Mathematics

Integration of Mathematics into Interdisciplinary Science Programs

E-mail Subject line: McMaster Study – Integrated Science at McMaster

I am inviting you to complete a brief 10-question online survey that will take about 5-10 minutes. As part of my research in pedagogy at McMaster University, I am carrying out a study to learn about the attributes of interdisciplinary teaching methods.

The risks involved in participating are minimal. You can stop at any time. This study has been reviewed and cleared by the McMaster Research Ethics Board. If you have any concerns or questions about your rights as a participant or about the way the study is being conducted you can contact:

The McMaster Research Ethics Board Secretariat
Telephone: (905) 525-9140 ext. 23142
O/O Research Office for Administration, Development and Support (ROADS)
E-mail: ethicsoffice@mcmaster.ca

I would like to thank you in advance for your time and consideration.

The following link will lead you to the consent form and letter of information, which contain more details about the survey.

The results of the survey will be available on avenue by the end of April 2014.

Miroslav Lovric
Professor of Mathematics
Department of Department of Mathematics and Statistics
McMaster University, Hamilton Ontario
Tel: 905-525-9140 Ext: 27362
lovric@mcmaster.ca
APPENDIX D

LETTER OF INFORMATION / CONSENT

A Study of Mathematics in Interdisciplinary Science Programs

Principal Investigator:  Co Investigator:
Dr. Lovric  Ana Lucic
Department of Mathematics and Statistics  Department of Mathematics and Statistics
McMaster University  McMaster University
Hamilton, Ontario, Canada  Hamilton, Ontario, Canada
McMaster University  McMaster University
(905) 525-9140 ext. 27362  (905) 339-6639
E-mail: lovric@mcmaster.ca  Email: lucica@mcmaster.ca

Purpose of the Study: This study investigates the ways mathematics is administered in integrated science programs in Canada. The main goal is to understand the benefits of these types of programs, and to assess how the mathematics component is incorporated. Students in these programs seem to be more successful academically, but it is not known exactly why this is the case. For the most part, mathematics is included in these programs, but it is not known specifically to what extent. These are the two main aspects that will be investigated in this study.

Procedures involved in the Research: Participation in this research involves completing an online survey. The survey should take approximately 5-10 minutes.

Potential Harms, Risks or Discomforts: The risks involved in participating in this study are minimal. You may feel uncomfortable with some of the questions asked, however you may skip any question you do not wish to answer. You can withdraw from the study at any time by exiting the survey altogether. You may worry about how you are responding and how others will react to your responses. Please remember, however, that you are participating anonymously.

Potential Benefits: The goal of this study is to understand the benefits of interdisciplinary science programs, and to assess the delivery of mathematics in such programs in order to optimize the students’ academic experience. The results of this study will be of interest to both instructors in these programs, as well as pedagogical researchers. We hope that what is learned as a result of this study will help us to better understand what students in interdisciplinary science programs need in order to be successful.

Confidentiality: You are participating in this research anonymously. No one, including the researchers, will know that you have participated. The information/data you provide will be kept in a locked desk/cabinet where only we will have access to it. Information kept on a computer will be protected by a password, and raw data collected from LimeSurvey will be kept on a password-protected account. Once the study is complete, an archive of the data, without identifying information, will be maintained for up to five years after completion of the study.

Participation and Withdrawal: If you decide to participate, you can withdraw at any time by simply exiting the survey. If you do not want to answer some of the questions, you do not have to,
but can still be in the study. Once you have submitted your responses, you will not be able to withdraw since we will not be able to identify which responses are yours.

Information about the Study Results: We expect to have this study completed by approximately April 2014. A summary of the results will be posted on avenue2learn, under the ISCI course heading (ISCI 1A24/ISCI 2A18/ISCI 3A12/ISCI 4A12).

Questions about the Study: If you have questions or need more information about the study itself, please contact one of the investigators at: lovric@mcmaster.ca or lucica@mcmaster.ca.

This study has been reviewed by the McMaster University Research Ethics Board and received ethics clearance. If you have concerns or questions about your rights as a participant or about the way the study is conducted, please contact:

McMaster Research Ethics Secretariat
Telephone: (905) 525-9140 ext. 23142
c/o Research Office for Administrative Development and Support
E-mail: ethicsoffice@mcmaster.ca
9.3 Survey Questions for Part B

1. What year are you in?
   First
   Second
   Third
   Fourth

2. Please rank your favourite science subjects (1-most favourite, 5-least favourite).
   Biology
   Chemistry
   Earth and Environmental Science
   Mathematics
   Physics

3. The amount of ____________ integrated into the program is too much, too little, or just enough.
   Biology
   Chemistry
   Earth and Environmental Science
   Mathematics
   Physics

4. Agree or Disagree: The program would benefit from the inclusion of:
   Computer Programming
   Statistical Methods

5. Do you think math is important as an integral part of interdisciplinary studies?
   Why or why not?

6. Please choose your three (3) favourite aspects of the iSci program.
   Having iConS instead of traditional lectures
   Independent research
   Integration between disciplines
   Integration of course content into projects
   Interactions with peers
   Interactions with professors
   Prevalence of group work
   Scientific literacy classes
   Small class sizes
7. What do you wish to take away from a degree in Integrated Science?

8. What was your admission average for iSci?
   - 0-80%
   - 81-85%
   - 86-90%
   - 91-95%
   - 96-100%

9. Agree or Disagree:
   - I enjoy iSci classes more than traditional classes
   - I get better grades in iSci classes than in traditional classes
   - I learn more in iSci classes than in traditional classes
   - I prefer group work to individual work
   - I prefer smaller class sizes
   - Other (can include comments)

10. Agree or Disagree:
    - I have a natural aptitude for science
    - I am happy with my academic experience in the program
    - I am happy with my social experience in the program
    - There is a sense of belonging among the students in the program
    - I have enough time for extracurricular/social activities
    - Other (can include comments)
9.4 Survey Questions for Part C

1. What program are you in now?

2. How do you think you would have done in a regular science program from the beginning?

3. Would you say you have a natural aptitude for math and/or science?

4. How are your grades now?

5. Do you feel the program was truly integrate?

6. What impact do you think the small class size had on your academic performance?

7. How did you feel about the program as a whole?

8. Why did you choose iSci in the first place?

9. Were your course timetables reasonable?

10. Is there a sense of belonging in the program?

11. Why did you leave the program?

12. Is there anything you miss about the program?