MSc.CS: Program Learning Outcomes

The primary outcome of the MSc program in Computer Science is to produce outstanding computer scientists who are capable of conducting quality research in an ethical manner. They will have a deep understanding of their research domain within computer science and will have the potential to make complete a higher degree and contribute to the private sector upon completion. The program is structured with one public seminars, and an oral defence of a written thesis. Additionally, each student will be required to take CIS*6890: Technical and Communication Research Methodology, in addition to four graduate level courses. Two of the courses must be outside the domain of the thesis research to demonstrate breadth. I is expected that graduates will also display strong technical communication skills, both written and oral.

Critical and creative thinking:

The thesis component of the MSc requires the application of independent critical and creative thinking, applying logic principles after significant inquiry and analysis. Problem solving with a some degree of innovation is at the core of computer science research. Depth is thus obtained through the thesis. Breadth of the discipline is required as a pre-requisite through undergraduate studies. Moreover, a total of 5 graduate courses must be completed (including CIS*6890), where at least two (not including CIS*6890) have content outside the domain of the thesis research.

Literacy:

Students will develop an enhanced level of information and technological literacy related to their chosen field of Computer Science to complete their MSc thesis. These literacy skills will be advanced through taking CIS*6890, other required graduate courses and the production of a MSc thesis. To complete the thesis component, students will be expected to extract material from a variety of resources, assess the quality and validity of the material, and apply it to make contributions to the research domain.

Global Understanding:

Computer science technology and research is inherently global in nature. Computer science research crosses borders and computer programs and the core of computer programming is a universal machine language.

Communicating:

The program is structured with one public seminars and an oral defence. Additionally, each student is also require to take CIS*6890: Technical and Communication Research Methodology, which specifically targets this learning outcome. Moreover, a written thesis must be orally defended. With the completion of these elements, a student will be able to interact effectively with a variety individuals and groups, conveying information in a variety of formats including both oral and written communication.

Professional and Ethical Behaviour:

Completing the MSc program requires a student to become a mature researcher. Many professional skills are learned along the way, including the leadership abilities of setting and working to internal deadlines to plan, conduct, and disseminate research through the writing of a thesis. Teamwork is also an important part of a MSc program. A student must work closely and congenially with many people, including their supervisor and supervisory committee to conduct their research. Learning the above skills and knowledge is core to producing a defendable MSc thesis.

Critical and Creative Thinking	**(see above)**

Learning Outcomes and Associated Skills	**Degree Program Outcomes**
1. Independent Inquiry and Analysis	I. Thesis II. Required coursework
2. Problem Solving	I. Thesis II. Required coursework
3. Creativity	I. Thesis II. Required coursework
4. Depth and Breadth of Understanding	I. Thesis II. Required coursework

Literacy	**(see above)**

Learning Outcomes and Associated Skills	**Degree Program Outcomes**
1. Information Literacy	I. Thesis II. Required coursework
2. Quantitative Literacy	I. Thesis II. Required coursework

	3. Technological Literacy	I. Thesis II. Required coursework
	4. Visual Literacy	I. Thesis II. Required coursework

Global Understanding	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Global Understanding	I. Thesis
	2. Sense of Historical Development	I. Thesis
	3. Civic Knowledge and Engagement	N/A
	4. Intercultural Knowledge and Competence	N/A

Communicating	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Oral Communication	I. Thesis defense II. Required coursework III. Seminar IV. CIS 6890: Technical communications
	2. Written Communication	I. Thesis II. Required coursework III. CIS 6890: Technical communications

	3. Reading Comprehension	I. Thesis II. Required coursework
	4. Integrative Communication	I. Thesis II. Required coursework III. Seminar IV. CIS 6890: Technical communications

Professional and Ethical Behaviour	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Teamwork	N/A
	2. Ethical Reasoning	I. Thesis
	3. Leadership	I. Thesis
	4. Personal Organization / Time Management	I. Thesis
	5. Intellectual Independence	I. Thesis

MCTI: Program Learning Outcomes *(as stated in the approved proposal)*

The MCTI program ensures that graduates possess a solid knowledge base and practiced lab-based skills to fill the growing need in the field of cybersecurity, cyber threat intelligence, and digital forensics. Upon completion of the program, students will have gained the knowledge, capabilities, and skills to be able to:

I. **Security Management**
   a) Plan, implement, and upgrade security measures and controls
   b) Protect information systems against unauthorized access, modification, and/or destruction
   c) Conduct internal and external security audits and forensics examinations
   d) Recommend and install appropriate tools and countermeasures to monitor and track existing and emerging threats in different cyber environments

II. **Analysis of Software and Data Analytics**
   a) Maintain data for analysis and monitor security access
   b) Analyze security breaches to conduct root cause analysis
   c) Anticipate security alerts, incidents, and disasters and reduce their likelihood
   d) Conduct vulnerability testing, risk analyses, penetration testing, and security assessments
   e) Manage and develop indications of compromise and indications of attack on network, intrusion detection, and prevention systems

III. **Security Architecture**
   a) Develop security roadmaps and strategic plans to manage and govern enterprise cyber security
   b) Design and architect security solutions in correspondence with existing and emerging threats to the enterprise
   c) Recommend security technologies and compensating controls and intelligence tools, tactics, and procedures

IV. **Professional Capacity**
   a) Demonstrate transferable skills necessary for employment including initiative, professional responsibility, accountability, and decision making in complex situations
   b) Demonstrate ethical behavior consistent with academic integrity and the professional code of ethics as required in the field of cybersecurity
   c) Demonstrate ability to conduct in-depth research about different cyber threats and prepare relevant technical and non-technical reports

The MCTI program addresses each of the University of Guelph's Learning Outcomes for graduate programs accordingly:

Critical and Creative Thinking	Analyzing cybersecurity threats and solutions will provide students with the training required to creatively handle this ever-evolving landscape.	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Independent Inquiry and Analysis	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	2. Problem Solving	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture Methods
	3. Creativity	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	4. Depth and Breadth of Understanding	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture

Literacy	Students will develop an enhanced level of information and technological literacy related to cybersecurity threats and defenses. These literacy skills will be advanced through active learning techniques within courses taught in a lab setting.	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Information Literacy	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	2. Quantitative Literacy	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	3. Technological Literacy	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture

	4. Visual Literacy	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture

Global Understanding	As cybersecurity attacks can be initiated from anywhere, this program and its teachings are inherently of global concern.	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Global Understanding	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	2. Sense of Historical Development	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	3. Civic Knowledge and Engagement	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	4. Intercultural Knowledge and Competence	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture

Communicating	Students will demonstrate their ability to effectively summarize and communicate security threats to audiences of both an academic and non-academic nature. At the end of their project, students will orally present their work to an audience of their peers.	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Oral Communication	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture

	2. Written Communication	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	3. Reading Comprehension	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture
	4. Integrative Communication	I. Security Management II. Analysis of Software and Data Analytics III. Security Architecture

Professional and Ethical Behaviour	The security industry operates with strict codes of ethics. As a result, students will know how to identify situations involving potential ethical issues and propose recommendations based on professional values and ethical principles. In addition to a short online unit on ethics taken by each student at the start of the program, each individual course will discuss professional and ethical behavior within its particular context.	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Teamwork	IV. Professional capacity
	2. Ethical Reasoning	IV. Professional capacity
	3. Leadership	IV. Professional capacity
	4. Personal Organization / Time Management	IV. Professional capacity
	5. Intellectual Independence	IV. Professional capacity

PhD.CSCI: Program Learning Outcomes *(adapted from the approved proposal)*

The objectives of the interdisciplinary PhD in Computational Sciences are as follows:

- To produce interdisciplinary scholars who are capable of tackling emerging problems in science and humanities through investigation and application of current computer technologies. This objective will be met by requiring full-time study in a research-based program targeted at students and professionals who wish to engage in research topics that that link topics of traditional computer science with some other discipline. This perspective recognizes that by the 21st century there is no other discipline like computer science that intersects virtually every other one in the sciences and humanities. All have been "colonized" by computerization. Their successes and future advances depend on more and smarter use of computer technology. Such an interdisciplinary degree offers the potential to break down the conventional silos of knowledge, and train High-Quality Personnel (HQP) who are better able to apply computer-based computational techniques to a wide variety of problem areas.

- To cultivate and engage a large interdisciplinary faculty, within the resource constraints of the university, to tackle emerging problems through the investigation and application of computer technology. This objective will be met by bringing together 42 faculty from the disciplines of Biology, Computer Science, Economics, Engineering, English, Geography, History, Psychology, Statistics, and Veterinary Medicine. This approach draws on the strengths of the wider university community, and will be more sustainable in an era of continuing resource challenges faced by all academic units across the university.

- To provide students with the opportunity to study computing within the context of another discipline commensurate with their interests and career goals. This objective will be met by allowing students, in conjunction with their advisory committee, to plan an individualized course of study. All graduates will have a demonstrable competence in the assessment of existing literature, research conceptualization and design, quantitative research methods and data-analysis techniques.

- To train graduates to communicate scientific and technological findings effectively to professionals working in other research areas. This objective will be met by requiring all students enrolled in the program to attend and present at interdisciplinary seminars.

- To enrich the academic environment for the faculty and students at other levels of study. The presence of interdisciplinary PhD students will provide critical eyes and creative minds for faculty, more mature examples of scholars compared to Masters' students, and strengthened learning environment to undergraduate students through enhanced teaching assistance.

Critical and creative thinking: The thesis component of the PhD requires the application of independent critical and creative thinking, applying logic principles after significant inquiry and analysis. Problem solving with a high degree of innovation is at the core of computational research. Depth is thus obtained through the thesis. Breadth of understanding is achieved through the interdisciplinary nature of the program. Students are required to achieve a strong understanding of the application and the appropriate methods of computation that can be applied to this area. They will also gain exposure to a range of applications and computational techniques through the required seminar course (CIS 6890).

Additionally, students are expected to prepare and present scholarly publications.

It can appear that the application of computation to a research area is simply a matter of applying a well-understood computational method to a large collection of data to produce a thesis result. This is not the case because it does not demonstrate any understanding of what is novel or important in the research. For the student in this program, independent thought will be necessary to identify and develop a research strategy that will produce results that are meaningful to their discipline.

Much of a Doctoral program is focused on the individual work of the student so the idea that they require a ***love of learning*** is considered an implicit part of the degree. There are learning opportunities for students in this program to expand their breadth of knowledge that go beyond their individual studies. Student will be provided with experience of other disciplines through the seminar course. This will allow them to experience a range of different disciplines and encourage them to understand the aspects that are important to those disciplines. The interdisciplinary nature of this program also encourages learning in that the student will need to develop an understanding of the relevant linkages between computation and the application area.

The ***forms of inquiry*** that will be examined in this program are restricted by the limitations imposed by computation. In return for accepting this limitation the benefit achieved through the computational approach the ability to find results that would otherwise be impractical. This means that the forms of inquiry used in computation tend to be restricted to those that tend to involve the management of large quantities of data and numerical operations. There are several research areas that focus on these activities and students in this program will gain a great deal of experience in the area that is applicable to their research.

Students will also receive an exposure to other computational forms of inquiry through the seminar course in which they are required to participate. This will expose them to different approaches to inquiry and provide them with exposure to the breadth of computational forms of inquiry. Students will also be required to take a research methodology course that will focus on the methods of research and proof which are commonly used with computational methods.

Literacy: The ***literacy*** component for this degree is substantial. Students will be required to research their application area and the computational techniques necessary for the development of a thesis proposal and thesis document. This will involve the analysis of the current literature in both areas and the synthesis of this material into a thesis proposal and document.

Furthermore, there is an inherent amount of ***numeracy*** involved in most computing activities due to the mathematical terms which are used to represent many concepts in a computational system. Due to this representation some level of numeracy will likely be a part of any thesis under this degree. The degree to which numeracy is a part of a thesis depends on the thesis topic that the student pursues but it would not be unusual if most thesis involved some numerical component for statistical analysis or data management. This will increase to a very large component if the application area involves a numerically intensive topic such as Mathematics, Statistics, or Physics.

Global Understanding: Global understanding plays a relatively minor part in the computational disciplines. Computation is an artifact of machine culture so there is little understanding of the human condition that can be gained from it. The application area to which the computation is applied may have a rich global understanding component but when it is combined with computation its focus shifts away

from the human and towards computational understanding. The results achieved through this merger of computation and application may provide insights into global understanding of the application area but the process used to achieve these results will not likely provide such insights.

Students will be required to perform a literature survey as part of their research. This material will be necessary for their qualifying examination and their thesis document. This will include a survey of the history of their application area and the use of computation as in that area. As a result of this study students will be knowledgeable of the current approaches to applying computation to their application area. They will also be aware of past approaches and why they are either still in use or have been discarded in favour of other techniques.

Communicating: The program is structured with two public seminars, a qualifying exam (QE) and an oral defence. Additionally, each student is also require to take CIS*6890: Technical and Communication Research Methodology, which specifically targets this learning outcome. Moreover, a written thesis must be orally defended and students are expected to prepare and present scholarly publications. With the completion of these elements, a student will be able to interact effectively with a variety individuals and groups, conveying information in a variety of formats including both oral and written communication.

Professional and Ethical Behaviour: In order to achieve the above outcomes, students will develop their personal organization and time management skills, and the research related to their written thesis will demonstrate their intellectual independence. All of the above enhancing their professional and ethical behaviour. Academic integrity and intellectual independence is central in the completion of the PhD thesis.
Moral maturity involved with this program are of greater concern to the application area than they are to the computational component. Once the application area is combined with computation the focus of the work becomes primarily technical. The moral principles which guide the research must be derived from the application area and be determined before the decision to apply computation to the problem.

Critical and Creative Thinking	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Independent Inquiry and Analysis	I. PhD Thesis
	2. Problem Solving	I. PhD Thesis

	3. Creativity	I. PhD Thesis
	4. Depth and Breadth of Understanding	I. PhD Thesis

Literacy	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Information Literacy	I. PhD thesis
	2. Quantitative Literacy	I. PhD thesis
	3. Technological Literacy	I. PhD thesis
	4. Visual Literacy	I. PhD thesis

Global Understanding	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Global Understanding	I. PhD thesis
	2. Sense of Historical Development	I. PhD thesis
	3. Civic Knowledge and Engagement	N/A
	4. Intercultural Knowledge and Competence	N/A

Communicating	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Oral Communication	I. PhD thesis II. QE III. Required seminars IV. CIS 6890: Technical communications
	2. Written Communication	I. PhD thesis II. QE III. CIS 6890: Technical communications
	3. Reading Comprehension	I. PhD thesis II. Required coursework
	4. Integrative Communication	I. PhD thesis II. QE III. Required seminars IV. CIS 6890: Technical communications

Professional and Ethical Behaviour	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Teamwork	N/A
	2. Ethical Reasoning	I. PhD thesis
	3. Leadership	I. PhD thesis
	4. Personal Organization / Time Management	I. PhD thesis
	5. Intellectual Independence	I. PhD thesis

PhD.CS: Program Learning Outcomes *(as stated in the program proposal)*

The primary outcome of the proposed PhD program is to produce outstanding computer scientists who are capable of conducting high-quality research in an ethical manner. They will have a deep understanding of their research domain within computer science and will have the potential to make significant contributions to the Academy and in the private sector upon completion. The program is structured with two public seminars, a qualifying exam and an oral defence of a written thesis. Additionally, each student will be required to take CIS*6890: Technical and Communication Research Methodology, in addition to two to four graduate level courses. Thus, it is expected that graduates will also display excellent technical communication skills, both written and oral.

Critical and creative thinking:

The thesis component of the PhD requires the application of independent critical and creative thinking, applying logic principles after significant inquiry and analysis. Problem solving with a high degree of innovation is at the core of computer science research. Depth is thus obtained through the thesis. Breadth of the discipline is required as a pre-requisite through undergraduate and Master's studies. Moreover, a total of 8 graduate courses must be completed (including CIS*6890), where at least four (not including CIS*6890) have content related to computer science. This requirement includes courses from previous degrees, where a Master's thesis counts for one course. Additionally, students are expected to prepare and present scholarly publications.

Literacy:

Students will develop an enhanced level of information and technological literacy related to their chosen field of Computer Science to complete their PhD thesis. These literacy skills will be advanced through taking CIS*6890, other required graduate courses and the production of a PhD thesis. To complete the thesis component of the PhD, students will be expected to extract material from a variety of resources, assess the quality and validity of the material, and apply it to make new and significant contributions to the research domain.

Global Understanding:

Computer science technology and research is inherently global in nature. Computer science research crosses borders and computer programs and the core of computer programming is a universal machine language.

Communicating:

The program is structured with two public seminars, a qualifying exam (QE) and an oral defence. Additionally, each student is also require to take CIS*6890: Technical and Communication Research Methodology, which specifically targets this learning outcome. Moreover, a written thesis must be orally defended and students are expected to prepare and present scholarly publications. With the completion of these elements, a student will be able to interact effectively with a variety individuals and groups, conveying information in a variety of formats including both oral and written communication.

Professional and Ethical Behaviour:

Completing a PhD program requires a student to become a mature, professional researcher. Many professional skills are learned along the way, including the leadership abilities of setting and working to internal and external deadlines to plan, conduct, and disseminate research to the scientific community. PhD students also learn to become part of the large scientific, professional community as they publish their work at conferences, workshops, journals, etc. A substantial part of learning to work within this community is to learn the professional norms around academic integrity and ethical behaviour. Teamwork is also an important part of a PhD program. A student must work closely and congenially with many people, including their supervisor(s) and supervisor committee to conduct and publish their research. They also work with the larger scientific community as they publish their work, learning to effectively take feedback, integrate it into their work and improve its quality. Learning the above skills and knowledge is core to producing a defendable PhD thesis.

Critical and Creative Thinking	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Independent Inquiry and Analysis	I. PhD Thesis II. Required coursework
	2. Problem Solving	I. PhD Thesis II. Required coursework
	3. Creativity	I. PhD Thesis II. Required coursework
	4. Depth and Breadth of Understanding	I. PhD Thesis II. Required coursework

Literacy	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Information Literacy	I. PhD thesis II. Required coursework

	2. Quantitative Literacy	I. PhD thesis II. Required coursework
	3. Technological Literacy	I. PhD thesis II. Required coursework
	4. Visual Literacy	I. PhD thesis II. Required coursework

Global Understanding	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Global Understanding	I. PhD thesis
	2. Sense of Historical Development	I. PhD thesis
	3. Civic Knowledge and Engagement	N/A
	4. Intercultural Knowledge and Competence	N/A

Communicating	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Oral Communication	I. PhD thesis II. Required coursework III. Required seminars IV. CIS 6890: Technical communications V. QE

	2. Written Communication	I. PhD thesis II. Required coursework III. CIS 6890: Technical communications IV. QE
	3. Reading Comprehension	I. PhD thesis II. Required coursework
	4. Integrative Communication	I. PhD thesis II. Required coursework III. Required seminars IV. CIS 6890: Technical communications V. QE

Professional and Ethical Behaviour	**(see above)**	
	Learning Outcomes and Associated Skills	**Degree Program Outcomes**
	1. Teamwork	N/A
	2. Ethical Reasoning	I. PhD thesis
	3. Leadership	I. PhD thesis
	4. Personal Organization / Time Management	I. PhD thesis
	5. Intellectual Independence	I. PhD thesis