AI Master's Goal: Supporting Ontario's growing AI ecosystem through capacity building and helping companies and labs source talent.

Vector Institute Guidance for AI-Related Master's Programs

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VECTOR INSTITUTE GUIDANCE FOR AI-RELATED MASTER'S PROGRAMS

BACKGROUND AND CONTEXT

The AI master's initiative of the Vector Institute (Vector) was established to support Ontario's growing AI ecosystem. Increasing the number of artificial intelligence (AI)-related master's graduates will help create a high-flow pipeline for Ontario's AI companies to source talent. The province has committed to this initiative in partnership with Vector. More information about AI master's initiative is provided in the Appendix.

This document has been prepared to provide guidance that supports and enables universities who are interested in offering new and/or enhanced AI-related master's programs. The document integrates the results of consultations that took input and advice from over 150 individuals, including a working group established by Vector comprising representatives from universities, government ministries, Vector industry sponsors and health sector organizations.

The consultations and working group identified eight priority skills/competencies for core technical AI-related master's graduates:

1. Technical computing skills with, where relevant to the AI-related program's field of study, a particular focus on:
   - Visualizing data and results using appropriate software tools and libraries
   - Exhibiting good software engineering practices (e.g., code optimization, version control, software testing)
   - Programming in more than one computer language, choosing the most suitable language for the task
2. Computational thinking skills with, where relevant to the AI-related program's field of study, a particular focus on:
   - Formulating problems in a way that enables the use of computers and other tools to help solve them
   - Logically organizing and analyzing data
   - Representing data through abstractions such as models and simulations
3. Mathematics and statistics related to AI
4. Integration skills (i.e., the ability to integrate technical computing skills, computational thinking and knowledge and skills related to the domain in which the AI-related work is performed)
5. Practical application skills related to AI
6. Core methodological skills related to AI
7. Collaboration and communications skills
8. Knowledge of ethics and societal implications of AI

The consultation participants and working group members agreed that the AI-master's initiative should also support complementary AI-related master's graduates, i.e., master's graduates who have complementary knowledge and skills (including business skills, implementation skills and sector knowledge), who can work effectively on interdisciplinary teams helping to design, evaluate, refine and implement practical AI-related solutions and technologies that meet business and end user needs in real world settings.

GENERAL CONSIDERATIONS

AI-related fields include, but are not limited to: data science, machine learning and deep learning, computer vision, natural language understanding, intelligent robotics, knowledge representation and reasoning, intelligent agents, intelligent user interfaces, and intelligent medicine.

The working group has determined that, at this time, a guidance document alone cannot ensure that the essential requirements for AI-related master's programs are fulfilled because (a) it is not possible to issue guidance that speaks to all the potential variations in program design and (b) one or more expert panels will need to be involved to ensure that varying approaches to the AI-related content of new master's programs are of sufficient substance to meet employer needs.

Accordingly, Vector will establish one or more panels to operationalize the guidance presented in this document. The panel(s) will assess programs proposed by universities with demonstrable strength related to AI to determine whether the programs will be recognized by Vector as meeting the essential requirements. The process for institutions to work with the panel(s) will be established as soon as practicable and will require institutions to submit a brief structured narrative foreground statement describing how the program will produce the required essential program level learning outcomes complemented with selected materials – that generally exist already – which support the claims in the narrative (e.g., course outline, curriculum vitae for instructors, syllabus, materials for within-institution quality assurance, completed degree level expectations tables in the case of programs undergoing Ontario Universities Council on Quality Assurance review, etc.). For clarity, the Vector panel(s) will not duplicate, or require as much information as, formal quality assurance or accreditation processes. Institutions should contact AImasters@vectorinstitute.ai to ensure that they have the most current version of the structured narrative template before they begin submissions for panel consideration.

All master's programs that are recognized as being AI-related by Vector will need to fulfill the essential requirements and articulate program level learning outcomes that are specific to the field of study. Fulfilling the requirements set out in this guidance document, including panel approval, will not necessarily result in an approved program. Standard approval and quality assurance processes for new or modified programs will continue to be in effect.

A subset of new and enhanced AI-related master's programs will far exceed the essential requirements presented in this document and will produce world-class graduates. Vector will work with employers and AI experts to develop guidance and supports for world-class AI-related master's programs.

Vector will have a role in disseminating examples of programs and program elements that meet the essential requirements and programs that are deemed to be world-class, so that these programs can serve as models for institutions looking to enhance their own programs and/or develop new AI-related content.

Vector will recognize new and enhanced core technical AI-related master's programs that are science, technology, mathematics and engineering (STEM) programs. These core technical AI-related master's programs will often be in computer science, engineering, mathematics or statistics, but can also be in other fields such as physics or informatics. Core technical AI-related programs must fulfill the following essential requirements in order to be recognized by Vector:

1. The program includes at least three (3) curriculum components[1] with learning outcomes focused on AI-related methodologies and applications
   a. At least one (1) curriculum component with intended learning outcomes focused on the application of AI-related methodologies to ensure that graduates have knowledge and skills related to algorithms and representations regardless of their application area. The focus of the AI-related methodology component(s) will vary depending on the master's program but it is strongly recommended that a machine learning curriculum component be offered. Other options could include: neural networks, deep learning, graphical models, reasoning under uncertainty, pattern recognition, planning, logic, and other topics.
   b. At least one (1) curriculum component that involves studying an AI-related application area in-depth to ensure that graduates are able to apply AI-related methodologies and have knowledge of their limits in solving problems. The focus of the AI-related application component(s) will vary depending on the master's program, but could include: computer vision, computational linguistics (NLP), intelligent robotics, intelligent agents, intelligent medicine, and other topics.

2. The program has learning outcomes related to communication, teamwork and interdisciplinary practice related to AI. This requirement could be satisfied through different forms of learning including, but not limited to, an internship with academic supervision and an industrial supervisor, or a capstone or culminating project.

3. The program has learning outcomes related to the ethics and societal implications of AI. This requirement could be satisfied through different forms of learning including a dedicated curriculum component or a module within an AI-related methodology or AI-related application course, or a thread that is integrated through and across courses.

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[1] A curriculum component will often be a course (in-person or online) but a program could prepare master's graduates through various combinations of: classroom learning, distance learning, culminating or capstone projects, summer school, faculty-supervised research projects, etc. For clarity, a curriculum component could be a topic or competency that is developed as a thread through multiple courses as opposed to a stand-alone component.

Vector will recognize new and enhanced complementary AI-related master's programs that may be STEM, business, social sciences or humanities master's programs. These complementary AI-related master's programs will integrate AI-related content into master's programs with a focus of study that applies AI technologies (e.g., business, public health, environmental sciences). Complementary AI-related programs must fulfill the following essential requirements in order to be recognized by Vector:

1. The program includes at least three (3) AI-related curriculum components with program level learning outcomes that are focused on AI-related applications and/or methodologies related to the primary field of study. The learning outcomes will ensure that graduates have sufficient knowledge of the relevant AI-related applications and methodologies to be able to contribute to AI-related work, providing essential input to the development, evaluation, refinement and implementation of AI-related methods, tools, products and services in real world settings, particularly those in the primary field of study.

2. The program has learning outcomes related to communication, teamwork and interdisciplinary practice related to AI. This requirement could be satisfied through different forms of learning including, but not limited to, an internship with academic supervision and an industrial supervisor, or a capstone or culminating project.

3. The program has learning outcomes related to the ethics and societal implications of AI. This requirement could be satisfied through different forms of learning including a dedicated component or a module within an AI-related methodology or AI-related application component, or a thread that is integrated through and across courses.

Appendix A: Increasing the number of AI-related master's graduates
Context and Consultation Results

March 29, 2018

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Vector: Vision & Mission

Vision

Vector will drive excellence and leadership in Canada's knowledge, creation, and use of artificial intelligence (AI) to foster economic growth and improve the lives of Canadians.

Mission

- Vector will lead Ontario's efforts to build and sustain AI-based innovation, growth and productivity in Canada by focusing on the transformative potential of deep learning and machine learning
- Vector, together with its AI partners in other parts of Canada, will work with Canadian industry and public institutions to ensure that they have the people, skills, and resources to be best in class at the use of artificial intelligence
- Vector will support Canada's innovation clusters in artificial intelligence and focus on helping start-ups grow to become Canadian-based global leaders
- Vector will attract the best global talent focused on research excellence; Vector's researchers and academic partners will be part of a vibrant community of innovative problem solvers, working across disciplines on both curiosity-driven and applied research

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Provincial Government Announcement

Funding announced on October 18, 2018

…The goal is to increase the number of graduates from applied master's students in AI-related fields

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"AI-related" Master's Graduates

– AI refers to computers that can learn about the world flexibly, make inferences about what they see and hear, and achieve human-like understanding of information

Artificial Intelligence

Machine Learning
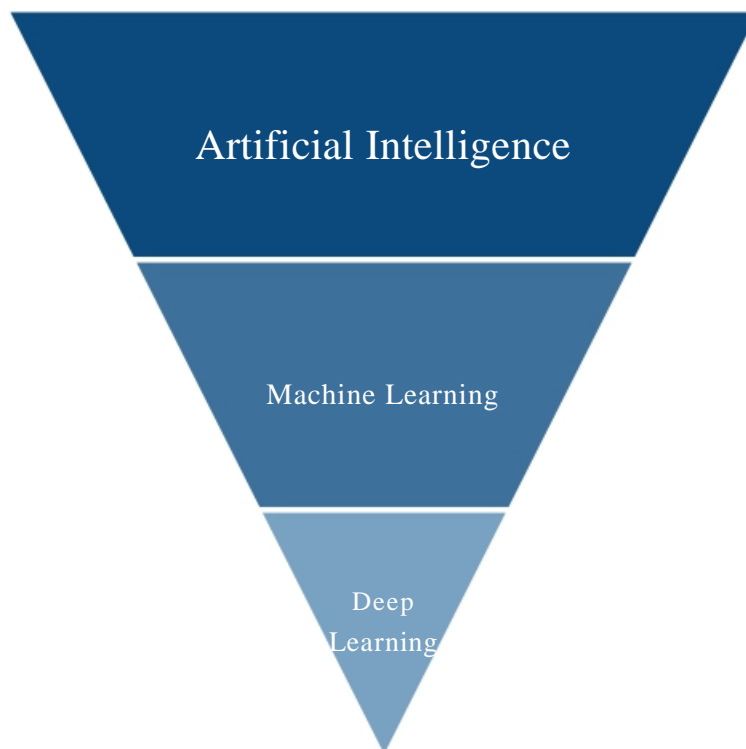
Deep Learning

– Vector's <u>research</u> focus is on machine learning and deep learning, but the scope of the AI-related master's initiative is much broader.

– AI-related fields include, but are not limited to: data science, machine learning and deep learning, computer vision, natural language understanding, intelligent robotics, knowledge representation and reasoning, intelligent agents, intelligent user interfaces, and intelligent medicine

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Opportunities for the AI-Master's Initiative

- Support and enable universities that are interested in offering new and enhanced AI-related master's programs

- Build interest in AI-related education by demonstrating the return on investment (ROI) of AI-related master's programs, including to students and their families

- Help employers find AI-talent and integrate interns and new graduates of AI-related master's programs into the workforce in meaningful ways, thus building Ontario's AI ecosystem

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Broad Strokes of the AI-Master's Initiative

- Two categories of master's programs will be recognized by Vector:

  – Core Technical AI-related Master's Programs

  – Complementary AI-related Master's Programs

- Three **program** "tracks":

  – Track 1: enhanced existing master's programs (mostly "on book", regulated tuition)

  – Track 2: bespoke new AI-focused master's programs (mostly "off book", full cost recovery)

  – Track 3: distributed delivery model of AI-related master's programs (i.e., models through which institutions that are not positioned to deliver an entire AI-related master's program make specific contributions toward degrees awarded in partnership with other institutions)

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Broad Strokes (continued)

- The AI-master's initiative will be flexible, support innovation, and be developed and implemented in partnership with universities and employers:

  - Essential requirements for core technical AI-related master's programs and complementary AI-related master's programs were developed based on extensive consultation and by a working group with diverse representatives

  - Essential requirements are defined in the least prescriptive way possible ("min specs" approach) so that institutions are free to innovate in varying ways to fulfill the requirements (i.e., no restrictions are placed on modes of learning)

  - Noting most AI-related master's graduates will immediately join the workforce, master's programs that produce graduates the proceed to PhDs are also in scope

  - Flexibility and commitment to work with employers to update essential requirements as employer needs change

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Process for Developing Essential Requirements

- Identify starting point list of essential skills and competencies that graduates would need to have*

- Modify list based on advice from Vector faculty and other university-based AI experts

- Broad consultation (150+ participants) on essential skills and competencies including live polling, online survey and meetings

- Establishment of working group to produce guidance document through a series of three meetings, considering consultation findings and their own experience

- Near final guidance shared with stakeholders

Working Group Members

Alison Paprica (Chair) – Vector Institute

Ayse Bener – Ryerson University

Brenda Brouwer* - Queen's University/Vector Institute+

Mark Daley – University of Western Ontario

Kevin Deluzio – Queen's University

Sven Dickinson – University of Toronto

Afsaneh Fazly – Thompson Reuters

Paul Fieguth – University of Waterloo

Michael Hillmer – Ministry of Health and Long-Term Care

Murat Kristal – York University

Muhammad Mamdani – Li Ka Shing Knowledge Institute

Bill Mantel – Ministry of Research, Innovation and Science/Ministry of Economic Development and Growth

John McLaughlin – Public Health Ontario

Tomi Poutanen – Layer 6 AI/TD

Andrea Proctor* – Vector Institute

Ladislav Rampasek~ – University of Toronto

Cindy Robinson – Council of Ontario Universities

Langis Roy – University of Ontario Institute of Technology

Marny Scully – Ministry of Advanced Education and Skills Development

Graham Taylor – University of Guelph/Vector Institute

* Non-voting member   ~ Student representative
+ Incoming Head, Academic Partnerships at Vector, secondment from Queen's beginning July 3 2018

Results of Consultations

- Of a list of six high-level skills/competencies, five were identified as essential for AI-related master's graduates by at least one of the four stakeholder groups, with notable variation in what different groups identified as essential

    – Technical computing skills (identified as essential by almost all Vector faculty and university stakeholders)

    – Computational thinking skills (identified as essential by almost all Vector faculty and university stakeholders)

    – Integration skills (identified as essential by almost all health stakeholders and Vector industry sponsors)

    – Mathematics and statistics (identified as essential by almost all Vector faculty)

    – Team work and communications skills (identified as essential by almost all Vector industry sponsors)

Results of Consultations cont.

	Core Technical AI-related Master's	Comple-mentary AI-related Master's	Comments entered as "Other Advice"	Total
Total number of text responses	159	138	14	311
% of comments that made reference to ethics and societal implications of AI	6%	6%	0%	5%
% comments that made reference to practical application of AI, "real world" etc.	19%	13%	21%	17%
% of comments that made reference to collaboration including multi-disciplinary AI teams	7%	17%	21%	12%
% of comments that directly referenced the need for core technical AI-related master's grads to have complementary knowledge/skills (e.g., related to business and field of application) or complementary AI master's grads needing technical knowledge/skills	9%	22%	0%	14%

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Examples of Advice on Most Needed Skills

What I hear from employees all the time is that business students need better technical skills while comp sci students need better business skills.

Practical, project-based application of deep learning and data analysis techniques to support marketing, sales and general business analytics.

Understand basics of AI/ML, but also what makes useful/valid data, ethics and governance related to data, and understanding opportunities to partner beyond just with AI experts.

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Timeline and Next Steps

- √   Vector compiles advice on essential requirements through live facilitated sessions with follow up via open online survey distributed more broadly
- √   Working group with university, ministry and employer representatives develop guidance on essential requirements
- √   Convert input on essential requirements into a plain language document that articulates employer needs and learning outcomes by the end of March
- Develop process for submission to panels and disseminate via COU and web meetings (as soon as practicable)
- Provide institutions with information about support for direct delivery costs of new and enhanced programs (as soon as practicable)
- Establish scholarship process (as soon as practicable)
- Communications, marketing and registrations for programs (as soon as practicable)
- Begin pairing students with internship opportunities with intent to integrate learnings into coordinated internship process established in 2018/19
- First students receive scholarships and commence studies (fall 2018)
- Establish coordinated internship working group (2018)
- Review first group of programs, make improvements (including updated and refined essential requirements)

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