BOARD #128: (Work-in-Progress) Bridging the Gap: Integrating AI into Undergraduate Interdisciplinary Engineering Curricula

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(Work-in-Progress) Bridging the Gap: Integrating AI into Undergraduate Interdisciplinary Engineering Curricula

Abstract

The integration of artificial intelligence (AI) into undergraduate engineering education is increasingly critical for preparing students for the evolving demands of the workforce. However, universities face challenges in effectively embedding AI concepts into interdisciplinary curricula. This work-in-progress study analyzes AI-infused undergraduate engineering programs at four Canadian universities, focusing on curriculum structure, learning outcomes, and student engagement with AI concepts.

Using the TASKS framework (Task, Affect, Skills, Knowledge, Stress), this study examines how AI is introduced within core and elective engineering courses, evaluating the extent to which students develop technical proficiency, problem-solving abilities, and adaptability to AI-driven technologies. The framework aims to enhance students' technical competencies while ensuring alignment with the Canadian Engineering Accreditation Board (CEAB) standards. In addition, the study highlights institutional efforts in AI integration, including faculty development initiatives and support structures that facilitate student learning.

Findings from this study contribute to the broader discussion on best practices for AI education in engineering, offering insights into curriculum design, accreditation considerations, and the student experience. By identifying gaps and opportunities in AI curriculum implementation, this research provides actionable recommendations to enhance AI literacy and workforce readiness among engineering graduates towards Industry 5.0.

1 Introduction

The rapid advancement of Artificial Intelligence (AI) is reshaping industries and redefining the competencies required of engineering professionals [1]. Therefore, integrating AI into various undergraduate engineering major has become imperative to prepare students for the evolving demands of the workforce. The infusion of AI into engineering education addresses the growing need for engineers proficient in emerging technologies. A report [2] highlights that AI is transforming higher education, particularly in STEM fields, by offering opportunities to enhance learning outcomes and better prepare students for AI-driven industries. This transformation necessitates a curriculum that not only imparts AI knowledge but also integrates it across various engineering disciplines, promoting an interdisciplinary approach to problem analysis and design. However, challenges persist in the seamless integration of AI into existing programs. A study [3] exploring the impact of AI tools on engineering education reveals that while students recognize the benefits of AI, there are concerns regarding adequate training and resource availability. Addressing these challenges requires a strategic approach to curriculum design, faculty development, and resource allocation, ensuring that the integration of AI enhances the educational experience without overwhelming existing structures. The whole process requires a tool or framework that can not only guide in identifying the challenges and barriers, but also provide the mean to enable a holistic solution and recommend actual facilitators.

Traditional engineering programs primarily focus on deterministic methods and analytical solutions, leaving minimal room for data-driven techniques like machine learning (ML) and predictive analytics, which are increasingly critical for modern days engineering problem-solving [4]. Furthermore, existing curricula often treat engineering disciplines in isolation, lacking an interdisciplinary focus that is essential for solving real-world challenges where AI is applied across domains (e.g., robotics integrating AI for autonomous decision-making, or embedded systems for IoT-based applications). This gap creates a disconnect between theoretical engineering education and the growing demand for AI-enabled solutions in professional practice. Thus, integrating AI into various engineering curricula becomes a crucial step to modernize undergraduate education and meet evolving industry needs. To response to this change, a few universities in Canada started to offer AI-infused engineering programs at undergraduate level [5], [6], [7], [8].

While we are still in Industry 4.0 [9], [10], [11] which is defined as the combination of Internet and emerging technologies and drives a new fundamental paradigm shift in industrial production [12], Industry 5.0 is approaching so fast that complements it by specifically putting research and innovation at the service of the transition to a sustainable, human-centric and resilient industry [13, p. 5]. In Industry 5.0, machines will work as an independent agent and collaborate with humans to make complex decisions. This new paradigm shift happens at the edge of traditional disciplines. Hence, it is necessary to redesign engineering curricula effectively and comprehensively to prepare the students and graduates adequately and appropriately. Modern solutions often bring new challenges, and AI is no exception. It is important to ensure that the students are taught on the essential concepts related to AI, including biases, fairness, equity, and ethics [14], [15], [16], [17] in these newly developed AI-infused programs.

In Canadian perspective, integrating AI into undergraduate engineering programs is essential for developing competencies on the one hand, and also that align with graduate attributes (GAs) set by the Canadian Engineering Accreditation Board (CEAB) on the other hand [18]. By analyzing current AI-infused programs in four Canadian Universities and identifying gaps in those curricula in accordance with societal needs, this paper aims to propose a few recommendations for effective AI integration, setting the stage for future work in designing comprehensive interdisciplinary engineering education models.

The latter parts of this study are organised as follows: section 2 will analyze the present AI-infused undergraduate programs at four Canadian universities. In Section 3, we will adopt TASKS framework to analyze the students' perceived tasks given in these programs of pursuit, their affects (motivation and stresses) towards the programs, the skills they are going to achieve and the earlier knowledge they must have to successfully complete the programs. In section 4, we will present the results and issues found in these curricula and discuss the strategies to be taken for successful AI integration. In section 5, we conclude the study.

2 AI-Infused Programs at Four Canadian Universities

This section focuses on analyzing the AI-integrated undergraduate programs offered by four Canadian universities: Carleton University**,** McGill University**,** Western University, and Ontario

Tech University**.** Through this analysis, the goals, objectives, curriculum structures, and program overviews of these programs will be compared to identify their unique strengths and limitations.

2.1 Goals and Objectives of the Programs

Carleton University's School of Computer Science (Faculty of Science) and McGill University's Faculty of Engineering focus on integrating AI within existing programs, offering specialization or minor options. In Carleton, they offer Computer Science AI and ML Stream (20 credits) with B.C.S Honours along with other streams for students pursuing computer science [5]. McGill offers Applied AI minor (25 credits) open to all engineering students [6].

Whereas, Western University's Electrical and Computer Engineering Faculty [7] offers several engineering programs that integrate Artificial Intelligence Systems Engineering (AISE) as an option, allowing students to earn dual degrees: a Bachelor of Engineering Science (BESc) in their primary engineering discipline (Civil, Mechanical, Electrical, Chemical, Mechatronics) and a BESc in AISE (non-accredited). These programs have limited enrollment, requiring students to complete the common first-year engineering curriculum with a minimum year-weighted average of 75% for eligibility. And Ontario Tech's Faculty of Engineering and Applied Science [8] offer more structured AI-focused engineering programs in Mechanical and Mechatronics, emphasizing interdisciplinary applications (Figure 1).

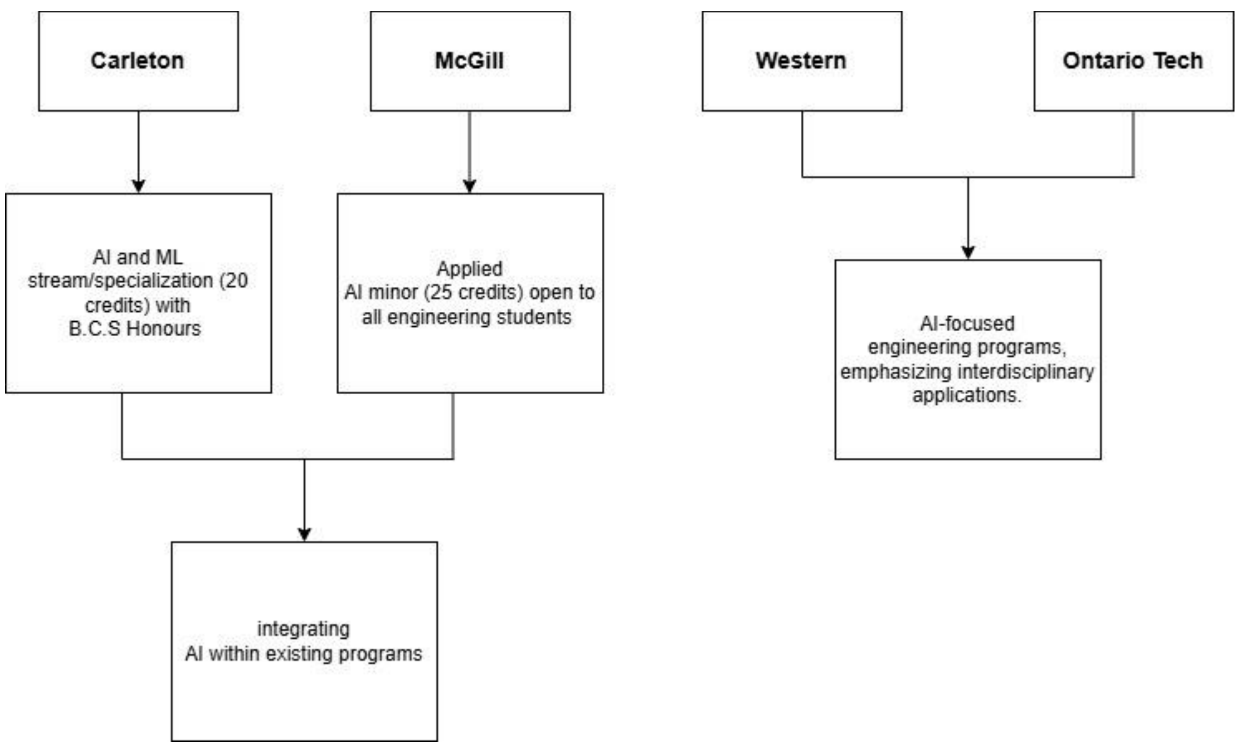

Figure 1. Goals and objective of undergraduate engineering programs on AI offered by four universities in Canada.

2.2 Curriculum Structure

The curriculum structure of AI-infused programs significantly impacts students' ability to apply AI concepts across engineering disciplines. Programs that offer streams or minors, for example, Carleton University allow flexibility for students to tailor their learning within existing computer science frameworks. However, this flexibility may come at the cost of limited exposure to interdisciplinary AI applications, as these programs often focus on theoretical foundations rather than applied and hands-on integration.

Conversely, standalone programs in Ontario Tech University and integrated interdisciplinary programs in Western University provide a more structured approach to embedding AI across various engineering disciplines. These programs offer specialized courses in AI/ML alongside traditional engineering topics, enabling students to explore practical applications of AI in fields like robotics, IoT, and system optimization.

While standalone and integrated curricula provide a stronger foundation for interdisciplinary learning, they may lack the customization opportunities found in stream-based or minor programs. Balancing specialization with flexibility is essential to ensure that graduates are not only technically proficient but also adaptable to evolving industry and societal demands.

2.2.1 Curriculum Structure of AI and Machine Learning Stream at Carleton University

Degree: Computer Science B.C.S. Honours - Artificial Intelligence and Machine Learning Stream
Course loads: 20 credits
Offered by: School of Computer Science, Faculty of Science
Student Eligibility: B.C.S. Honours students can choose this or other streams with different focuses.

A. Credits Included in the Major CGPA (9.5 credits)

1. 6.5 credits in:	
COMP 1405 [0.5]	Introduction to Computer Science I
COMP 1406 [0.5]	Introduction to Computer Science II
COMP 1805 [0.5]	Discrete Structures I
COMP 2401 [0.5]	Introduction to Systems Programming
COMP 2402 [0.5]	Abstract Data Types and Algorithms
COMP 2404 [0.5]	Introduction to Software Engineering
COMP 2406 [0.5]	Fundamentals of Web Applications
COMP 2804 [0.5]	Discrete Structures II
COMP 3000 [0.5]	Operating Systems
COMP 3004 [0.5]	Object-Oriented Software Engineering
COMP 3005 [0.5]	Database Management Systems
COMP 3007 [0.5]	Programming Paradigms
COMP 3804 [0.5]	Design and Analysis of Algorithms I

2. 1.5 credits in:	
COMP 3105 [0.5]	Introduction to Machine Learning
COMP 3106 [0.5]	Introduction to Artificial Intelligence
COMP 4107 [0.5]	Neural Networks

3. 1.5 credits from:
COMP 4905 [0.5] and 1.0 credit in COMP at the 4000-level, or
COMP 4906 [1.0] and 0.5 credit in COMP at the 4000-level, or
1.5 credits in COMP at the 4000-level

B. Credits Not Included in the Major CGPA (10.5 credits)

4. 1.0 credits in:	
MATH 1007 [0.5]	Elementary Calculus I
MATH 1104 [0.5]	Linear Algebra for Engineering or Science
5. 0.5 credits from:	
STAT 2605 [0.5]	Probability Models
or 0.5 credit in MATH at the 2000-level or above	
6. 0.5 credits in:	
STAT 2507 [0.5]	Introduction to Statistical Modeling I

7. 5.0 credits in Breadth Electives
8. 3.5 credits in free electives

The AI and Machine Learning stream at Carleton University equips students with both foundational and advanced knowledge in artificial intelligence. Core courses include COMP 3105 (Introduction to Neural Networks), focusing on neural network fundamentals and optimization techniques, and COMP 3106 (Introduction to Machine Learning), covering algorithms such as decision trees, clustering, and ensemble methods. The advanced course, COMP 4107 (Neural Networks), delves deeper into topics like deep learning, convolutional neural networks (CNNs), and recurrent neural networks (RNNs), emphasizing real-world AI applications. All the courses include 3 hours of lecture per week and are of 0.5 credits.

Students complete the stream through one of three pathways: The Project Pathway involves a practical research-focused project in COMP 4905 (Honours Project) comprising of 0.5 credits, the Thesis Pathway includes independent research culminating in COMP 4906 (Honours Thesis) comprising of 1 credit, or the Course-Only Pathway offers a selection of advanced 4000-level COMP courses, such as computer vision, reinforcement learning, and natural language processing.

2.2.2 Curriculum Structure of Applied AI Minor at McGill University

Degree: Bachelor of Engineering – Minor Applied Artificial Intelligence
Course loads: 25 credits
Offered by: Electrical and Computer Engineering, Faculty of Engineering
Student Eligibility: Open to all engineering students and designed to provide the foundation for applications of AI techniques in various fields of interest.

Students must complete 7 courses as follows. Up to three courses can be double counted with the major.

I. Required courses (3 credits)

COMP 250 [3]	Introduction to Computer Science

II. Complementary courses (19-22 credits)

Group A. 4 credits from:	
COMP 551 [4]	Applied Machine Learning
ECSE 551 [4]	Machine Learning for Engineers
COMP 551 and ECSE 551 cannot both be taken	

Group B. 3 credits from:	
ECSE 343 [3]	Numerical Methods in Engineering
MATH 223 [3]	Linear Algebra
MATH 247 [3]	Honours Applied Linear Algebra
MATH 271 [3]	Linear Algebra and Partial Differential Equations
Group C. 3 credits from:	
AEMA 310 [3]	Statistical Methods 1
CIVE 302 [3]	Probabilistic Systems
ECSE 205 [3]	Probability and Statistics for Engineers
MATH 203 [3]	Principles of Statistics 1
MATH 323 [3]	Probability
MECH 262 [3]	Statistics and Measurement Laboratory
MIME 209 [3]	Mathematical Applications
Group D. 9-12 credits from:	
COMP 445 [3]	Computational Linguistics
COMP 550 [3]	Natural Language Processing
COMP 579 [4]	Reinforcement Learning
ECSE 415 [3]	Introduction to Computer Vision
ECSE 446 [3]	Realistic Image Synthesis
ECSE 507 [3]	Optimization and Optimal Control
ECSE 526 [3]	Artificial Intelligence
ECSE 544 [4]	Computational Photography
ECSE 552 [4]	Deep Learning
ECSE 557 [3]	Introduction to Ethics of Intelligent Systems
MECH 559 [3]	Engineering Systems Optimization
Or any 400 or 500 level special topics courses in the area of artificial intelligence with the approval of the Electrical and Computer Engineering department.	

The B.Eng. Minor in Applied Artificial Intelligence at McGill University provides engineering students with a solid foundation for applying AI techniques across various fields of interest. The program, which is open to all engineering students, requires the completion of 22-25 credits and is designed to integrate seamlessly with their major, allowing up to three courses to be double counted. Under the guidance of advisor, students complete seven courses, forming one required course (COMP 250) and a choice of complementary courses across four groups.

The program begins with the required foundational course, COMP 250 (Introduction to Computer Science), providing essential programming and computational knowledge. Complementary courses are categorized into four groups. In Group A, students choose advanced machine learning courses, such as COMP 551 (Applied Machine Learning) or ECSE 551 (Machine Learning for Engineers), although only one may be taken. Group B focuses on linear algebra and numerical methods, with options like MATH 223 (Linear Algebra) or ECSE 343 (Numerical Methods in Engineering). Group C offers statistical foundations, including ECSE 205 (Probability and Statistics for Engineers) or AEMA 310 (Statistical Methods 1). Finally, Group D allows students to explore specialized AI applications, such as COMP 550 (Natural Language Processing), ECSE 552 (Deep Learning), or ECSE 557 (Introduction to Ethics of Intelligent Systems), as well as advanced topics like optimization and computer vision. But here there is no inclusion of practical research-focused project or thesis pathways similar to Carleton's. It potentially limits the scopes to get hands-on experience for the students of what they learn on AI. However, an admirable aspect is their inclusion of a course on AI ethics, which is crucial for equipping students with the knowledge and awareness needed to understand the societal implications of AI applications.

This structure equips students mostly with theoretical and applied knowledge, preparing them to address complex engineering challenges of recent time.

2.2.3 Course Content of AISE at Western University

Degree: Artificial Intelligence Systems Engineering (AISE) with following majors: Chemical, Civil, Electrical, Mechanical, or Mechatronics.
Course load: No details on total credit hours
Offered by: Department of Electrical and Computer Engineering, Faculty of Engineering

Western University's Artificial Intelligence Systems Engineering (AISE) program is a five-year concurrent degree that integrates AI specialization with traditional engineering disciplines, including Chemical, Civil (Structural and Environmental streams), Electrical, Mechanical, and Mechatronics Engineering. Students begin with a common first-year engineering curriculum and then proceed with discipline-specific courses combined with AI-focused subjects. Below is an overview of the course structure for each program from Year 1 to Year 5.

Common First Year (All Disciplines):

Course Code	Course Title
ES 1050	Introductory Engineering Design
ES 1022A/B	Engineering Statics
ES 1036A/B	Programming Fundamentals for Engineers
ES 1050	Calculus I
ES 1051A/B	Calculus II
ES 1021A/B	Linear Algebra for Engineers
ES 1023A/B	General Chemistry for Engineers

ES 1024A/B	Applied Mechanics
ES 1053A/B	Properties of Materials
ES 1052A/B	Engineering Communications

Chemical Engineering with AISE Specialization:

Year	Course Code	Course title
2	CBE 2206A/B	Chemical Engineering Thermodynamics I
	CBE 2290A/B	Chemical Process Calculations
	AISE 2205A/B	Introduction to Artificial Intelligence
3	CBE 3322A/B	Heat and Mass Transfer
	CBE 3315A/B	Chemical Reaction Engineering
	AISE 3351A/B	Machine Learning for Engineers
4	CBE 4415A/B	Process Dynamics and Control
	CBE 4424A/B	Biochemical Engineering
	AISE 4430A/B	AI Applications in Chemical Engineering
5	CBE 4497	Chemical Engineering Design Project
	AISE 4499	AISE Capstone Project

Civil Engineering (Structural Stream) with AISE Specialization:

Year	Course Code	Course title
2	CEE 2202A/B	Structural Mechanics
	CEE 2220A/B	Surveying
	AISE 2205A/B	Introduction to Artificial Intelligence
3	CEE 3326A/B	Structural Analysis
	CEE 3348A/B	Reinforced Concrete Design
	AISE 3351A/B	Machine Learning for Engineers
4	CEE 4441A/B	Steel Design
	CEE 4465A/B	Foundation Engineering
	AISE 4430A/B	AI in Structural Engineering
5	CEE 4497	Civil Engineering Design Project
	AISE 4499	AISE Capstone Project

Other majors focusing electrical, mechanical and mechatronic have the similar course structures in the 5th year as above and respective core courses in the other years. These interdisciplinary programs at Western University are designed to produce engineers proficient in their respective fields, with a strong foundation in AI, enabling them to develop innovative solutions across various engineering challenges. Each program includes a dedicated engineering design project specific to the discipline and an AISE capstone project in the final year, providing a well-balanced integration of theory and practical application.

2.2.4 Course Content of Mechanical and Mechatronics at Ontario Tech University

Degree: Mechanical Engineering - AI specialization, Mechatronics Engineering – AI specialization

Course load: 135 credits
Offered by: Faculty of Engineering and Applied Science

Year 1 (33 credits)		
Courses	**Mechanical Engineering**	**Mechatronics Engineering**
COMM 1050U	Technical Communications	Technical Communications
ENGR 1015U	Introduction to Engineering	Introduction to Engineering
MATH 1010U	Calculus I	Calculus I
MATH 1850U	Linear Algebra for Engineers	Linear Algebra for Engineers
PHY 1010U	Physics I	Physics I
CHEM 1800U	Chemistry for Engineers	Chemistry for Engineers
ENGR 1025U	Engineering Design	Engineering Design
ENGR 1200U	Introduction to Programming for Engineers	Introduction to Programming for Engineers
MATH 1020U	Calculus II	Calculus II
PHY 1020U	Physics II	Physics II
SSCI 1470U	Impact of Science and Technology on Society	Impact of Science and Technology on Society

Year 2 (33 credits)		
Courses	**Mechanical Engineering**	**Mechatronics Engineering**
MANE 2220U	Structure and Properties of Materials	
MATH 2860U	Differential Equations for Engineers	Differential Equations for Engineers
MECE 2230U	Statics	Statics
MECE 2310U	Concurrent Engineering and Design	Concurrent Engineering and Design
MECE 2320U	Thermodynamics	
ELEE 2790U	Electric Circuits	
ENGR 2100U	Computational Engineering Applications	Computational Engineering Applications
MECE 2420U	Solid Mechanics I	Solid Mechanics I
MECE 2430U	Dynamics	Dynamics
MECE 2860U	Fluid Mechanics	
STAT 2800U	Statistics and Probability for Engineers	Statistics and Probability for Engineers
METE 2010U		Circuits and Electronics
SOFE 2710U		Object Oriented Programming and Design
METE 2020U		Circuit Design for Mechatronics
METE 2030U		Electronics Applications in Mechatronics

There are 7 common courses between Mechanical and Mechatronics major in the second year.

Year 3 (36 credits)		
Courses	**Mechanical Engineering**	**Mechatronics Engineering**
ENGR 3150U	Artificial Intelligence and Machine Learning	Artificial Intelligence and Machine Learning
MANE 3190U	Manufacturing and Production Processes	
MECE 3030U	Computer-Aided Design	Computer-Aided Design
MECE 3270U	Kinematics and Dynamics of Machines	Kinematics and Dynamics of Machines
MECE 3350U	Control Systems	Control Systems
MECE 3420U	Solid Mechanics II	
ENGR 3360U	Engineering Economics	Engineering Economics
MECE 3210U	Mechanical Vibrations	
MECE 3220U	Machine Design	Machine Design
MECE 3230U	Thermodynamic Applications	
MECE 3390U	Mechatronics	
MECE 3930U	Heat Transfer	
MANE 2220U		Structure and Properties of Materials
MECE 2640U		Thermodynamic and Heat Transfer
MECE 2860U		Fluid Mechanics
METE 3100U		Actuators and Power Electronics
METE 3200U		Sensors and Instrumentation
METE 3350U		Microprocessors and Digital Systems

There are 6 common courses between Mechanical and Mechatronics major in the third year.

	Year 4 (30 credits)	Year 4 (33 credits)
Courses	**Mechanical Engineering**	**Mechatronics Engineering**
	Liberal Studies elective	Liberal Studies elective
ENGR 4170U	Deep Learning	Deep Learning
ENGR 4760U	Ethics, Law, and Professionalism for Engineers	Ethics, Law, and Professionalism for Engineers
ENGR 4950U	Capstone Systems Design for Mechanical, Automotive, Mechatronics and Manufacturing Engineering I	Capstone Systems Design for Mechanical, Automotive, Mechatronics and Manufacturing Engineering I
MECE 4290U	Finite Element Methods	
MECE 4210U	Advanced Solid Mechanics and Stress Analysis	
	Liberal Studies elective	Liberal Studies elective
ENGR 4951U	Capstone Systems Design for Mechanical, Automotive,	Capstone Systems Design for Mechanical, Automotive,

	Mechatronics and Manufacturing Engineering II	Mechatronics and Manufacturing Engineering II
ENGR 4270U	Machine Learning Applications	Machine Learning Applications
	Engineering elective	
MANE 4280U		Robotics and Automation
METE 4100U		Mechatronics Design
METE 4400U		Introduction to Real-time Embedded Systems
METE 4200U		Industrial Automation

There are 6 common courses/elements between Mechanical and Mechatronics major in the fourth year.

Ontario Tech provides two dedicated engineering programs [19], [20] with specialization on AI, offering a broader approach to applied AI solutions. The Mechanical Engineering program with an Artificial Intelligence specialization provides students with a comprehensive foundation in mechanical engineering principles, complemented by advanced AI coursework. This combination equips graduates with the skills to apply AI techniques to mechanical systems, enhancing innovation in areas such as automation, intelligent control, and predictive maintenance.

Similarly, the Mechatronics Engineering program with an Artificial Intelligence specialization blends mechanical, electrical, and computer engineering concepts with AI applications. Students gain expertise in designing and managing intelligent mechatronic systems, preparing them for careers in robotics, smart manufacturing, and other fields where AI-driven automation is essential.

Both programs emphasize a multidisciplinary approach, ensuring that graduates are well-prepared to address complex engineering challenges using AI technologies. Additionally, both programs include two capstone projects and a mandatory course on Ethics, Law, and Professionalism for Engineers, making the curriculum comprehensive and well-rounded. They also offer wide range of elective courses from Liberal Arts and Engineering that is a good opportunity for students to prepare adequately according to their goal.

The comparison of required AI courses and practical part in programs offered at the four Canadian universities are compiled in Table 1.

Table 1. Comparison of required AI courses and practical part in four Undergraduate Programs in Canada.

University	Core AI courses	Practical/Project Component
Carleton University	COMP 3105 (Neural Networks), COMP 3106 (Machine Learning), COMP 4107 (Advanced Neural Networks)	Project Pathway (COMP 4905) or Thesis Pathway (COMP 4906); optional hands-on courses at the 4000 level
McGill University	COMP 250 (Intro to Computer Science), COMP 551 or ECSE 551 (Applied Machine Learning), Advanced Topics (e.g., NLP, Reinforcement Learning)	Advanced complementary courses like Computer Vision, Deep Learning offer practical applications
Western University	AISE-specific courses across disciplines (e.g., AISE 2205, AISE 3351, AISE 4430 tailored to engineering fields)	Capstone projects and design courses tailored to AI applications in engineering disciplines
Ontario Tech University	Core AI-focused courses integrated into Mechatronics and Mechanical	Extensive labs, capstones, and AI-focused projects integrated into the curriculum

The comparison in terms of goals and aims, curriculum structure and overview of the programs in these four universities are listed in Table 2.

3 TASKS Framework Analysis for Students in AI-Infused Undergraduate Programs

As students are the core stakeholder of the mentioned AI-infused programs, the successful integration of these programs' curricula depends on the students' adherence and experience towards pursuing these programs.

TASKS [21] is a framework where it deals with the relationships between a task and the task accomplisher's affect (attitude, motivation), skills, knowledge and the mental stress of the task accomplisher associated with the tasks. In light of TASKS framework [21], below we will analyze the students' mental capabilities or the ASK (affect, skills and knowledge) towards the program they are enrolled in to accomplish. The equation below-

$$\boldsymbol{\sigma} = \frac{T}{\mathrm{A}*(\mathrm{K}+\mathrm{S})} \qquad (1)$$

Where knowledge (K), skill (S), and affect (A) are three key factors deciding the human mental capability to tackle a perceived workload (T) related to a given task ensuring to keep a best stress level ($\boldsymbol{\sigma}$) of the students in this given context. Maintaining the optimum stress level is important for students because humans perform best when their mental stresses are at an optimal level [22].

Table 2. Comparison of goals, objectives, curriculum structure and overview of AI-Infused Undergraduate Programs in Canada.

University	Goals/Objectives	Curriculum Structure	Program Overview
Carleton University	To provide a strong foundation in computer science with specialized training in Artificial Intelligence (AI) and Machine Learning (ML) [5]	- AI/ML stream within the Bachelor of Computer Science (Honours).	- Focuses on modern AI/ML techniques such as data mining, natural language processing, and deep learning. - Prepares students for careers in AI, software engineering, and research.
McGill University	To enhance engineering programs with AI applications, enabling students to tackle real-world problems using AI technologies [6].	- Minor in Applied Artificial Intelligence integrated with existing Bachelor of Engineering programs. - Interdisciplinary electives combining AI and core engineering disciplines.	- Offers applied courses in AI for disciplines like mechanical (MECH 559) and electrical engineering (ECSE 551). - Designed to develop hands-on AI skills for engineering applications and problem-solving.
Western University	To equip students with AI/ML skills while maintaining a strong foundation in traditional engineering disciplines [7]	- AI Systems Engineering program combined with core disciplines such as Chemical, Civil, Electrical, Mechanical, and Mechatronic Systems Engineering. - Specialized AI/ML courses integrated.	- Emphasizes AI-driven solutions in engineering fields like IoT, robotics, and system design. - Students graduate with expertise in both engineering fundamentals and AI technologies.
Ontario Tech University	To create AI-ready engineers who are proficient in both foundational engineering concepts and modern AI tools [8]	- Standalone Artificial Intelligence Engineering program. - Combines courses in AI, ML, programming, and systems design with traditional engineering topics.	- Focuses on applied AI solutions focused on Mechanical and Mechatronics - Prepares students for careers in AI, robotics, IoT, and software development. - Strong industry-alignment.

According to TASKS, we have ideal TASKS components for a given situation and we always get the corresponding actual scenarios for these because of barriers we face in real life. TASKS framework suggests the barriers could be of four kinds mainly: knowledge barriers, resource barriers, emotion barriers and logic barriers [21]. The gap between each actual and ideal scenario is created due to the barriers to implementation of tasks (Figure 2). In the context of this research, we need to find implementation barriers the students might face or facing to improve the existing programs offered by these universities in future.

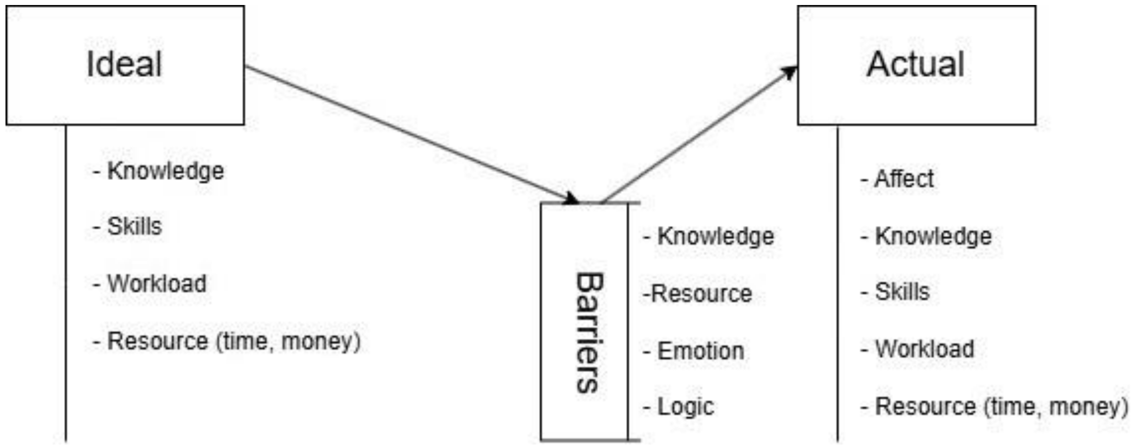

Figure 2. Implementation barriers for tasks (Ideal vs Actual).

3.1 Identifying Ideal TASKS Components for Students in these Programs

To identify the ideal task components, we need to follow two steps in TASKS, 1) workload analysis, and 2) skills and knowledge analysis. The goal of a workload analysis is to define "who" is "to do what" with "what resources" to complete a task. In skills and knowledge analysis, the output is the ideal skills and knowledge required to tackle the workload. In both steps, we need to answer the questions based on the framework provided by the TASKS framework [21]. Since, there is no emotion involved in ideal situation, here affect analysis is not needed and we can see there is no affect labelled in the left side of Figure 2.

The necessary tasks needed to be done by the students are rooted in understanding and learn the contents efficiently (workload and knowledge), make them skilled on the appropriate tools and getting a decent job offer after their graduation. To keep it short, the ideal TASKS component, or the workload, knowledge and skills for the students to attain from these programs are both aspirational (aligned with the program goals) and grounded in practical, societal, and industry needs as follows:

1. Students need to develop a solid foundation in AI concepts, for example, machine learning, data mining, natural language processing, supervised and unsupervised learning, neural networks and so on.
2. They must build the ability to apply AI tools (Strong programming abilities in Python, R, MATLAB etc.) and techniques to real-world interdisciplinary problems in fields like IoT, robotics, and system optimization.
3. To engage in hands-on projects and labs to solve engineering problems.
4. To collaborate in team-based projects across engineering disciplines, For example, AI applications in control systems and embedded systems.

3.2 Modeling the Students' Mental Capability (ASK)

Affect (A), skills (S) and knowledge (K) constitute students' mental capability. We need to understand students' actual mental capacity (or, the actual task components) in response to complete the tasks mentioned in section 3.1. The emotional responses (affects) associated with accomplishing tasks can be understood through factors such as attitude, motivation, feelings, stress, and external stimuli [23]. To perceive the above tasks, the students tend to respond emotionally (positive and negative) through several potential motivators and stressors as given below-

Motivators:

1. Some students could feel excitement about learning innovative AI technologies applicable to real-world challenges.
2. Some may feel motivated by the interest in working in interdisciplinary applications and team-based projects.
3. Good career prospects in high-demand fields such as AI engineering, IoT, and robotics.

Stressors:

1. Students may feel stressed by the overlapping workloads between AI courses and core engineering disciplines offered by Carleton and McGill.
2. Probable limited support (academic and technical) for interdisciplinary teamwork. For example, in AI integration across civil, mechanical, and electrical engineering offered by the programs at Western.
3. Students might feel pressure to learn advanced AI tools without sufficient prior programming experience, especially for the ones from traditional engineering programs (chemical, civil, mechanical etc).

Apart from the affect (A), knowledge (K) and skills (S) are the two other vital parts of students' mental capability. Often limited prior knowledge are not a strong barrier if a student is motivated enough. Also, the students will attain the skills throughout the journey while they continue to pursue the program. Below we list the actual skills to attain by the students from the programs-

Actual Skills Aim to Develop in Programs:

1. Carleton: Focuses heavily on AI/ML concepts but lacks interdisciplinary exposure.
2. McGill: Balances AI and engineering disciplines, offering broad technical skills. Limited hands-on opportunity.
3. Western: Provides strong interdisciplinary integration, building technical and team-based skills. Strong hands-on focus.
4. Ontario Tech: Ontario Tech emphasizes hands-on AI applications (two capstone projects) aligned with the major.

As we can see, the skills and knowledge pointed above are mainly involved and could be attained in the form of different tasks assigned to the students mentioned in section 3.1. However, the offered programs reveal certain gaps when compared to the ideal TASKS components we identified. These gaps will be discussed in detail in the later sections of this study.

4 Results and Discussion

In this section, we will discuss the barriers we identified to student implementation in these AI-infused programs and later we synthesize the results with the previous studies.

4.1 Barriers Identified to Implement Highest Student TASKS Performance

To identify the implementation barriers of four kinds, we apply the strategy as shown in Figure 3. The input here are the ideal and actual TASKS components discussed in section 3.1 and 3.2. The output is knowledge barriers, logic barriers, emotion barriers, and resources barriers, which are gaps between the ideal and actual TASKS components.

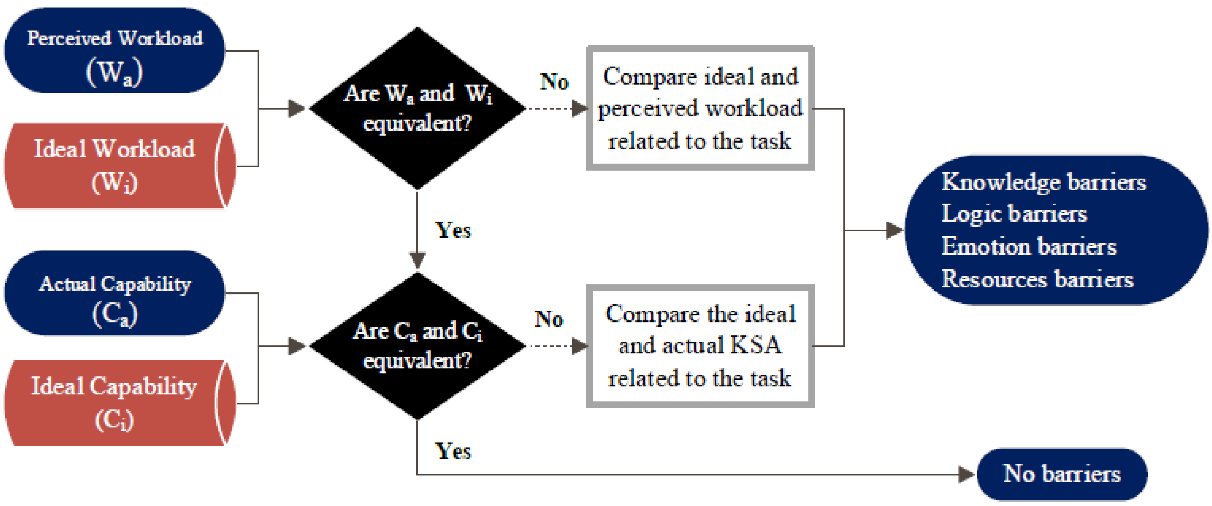

Figure 3. Process of Detecting Implementation Barriers [21].

From sections 2.1 and 2.2, we can observe that most of the AI-infused programs offered by the four universities are comprehensive. However, there are some important barriers we have identified (Figure 4). We are going to discuss each of those one by one below-

Emotion barriers: One crucial factor in any program's successful integration is not to make the students feel overwhelmed and keeping their stress in an optimum level. McGill University's Bachelor of Engineering – Minor Applied Artificial Intelligence allows student from all engineering major, but there is a high risk of overload due to the combined demands of AI courses and core courses.

Logic barriers: One critical gap identified across the programs is the insufficient focus on ethical AI practices and the broader societal impacts of AI technologies. Engineering ethics courses were introduced in certain programs but lack in ethical AI focus, such ENGR 4760U: Ethics, Law, and Professionalism for Engineers by Ontario Tech. Though McGill made a great initiative by introducing the course ECSE 557: Introduction to Ethics of Intelligent Systems (3 credits) that focused on discussing ethics and social issues related to AI and robotic systems. This course covers the consideration for normative values (e.g., fairness) in the design. Ethics principles, data and privacy issues, ethics challenges in interaction and interface design are also the contents of this course. However, the course should be made compulsory, rather the students were given other options to choose over this course. These are needed to implement to change the traditional thinking style [15], [24]. While these programs emphasize technical skills and interdisciplinary applications, they often overlook essential discussions around the responsible use of AI. This includes understanding biases in AI models, ensuring transparency in algorithmic decision-making, and addressing ethical dilemmas related to automation and privacy.

Knowledge Barriers: As we discussed in section 3.2, students from some majors could lack of prior programming knowledge and find it difficult to progress in their study. This could lead to emotional barrier too. As a consequence, they might not be able to continue the program. Even if they continue the program, they might struggle a lot. In such cases, flexibility should be provided by allowing students to adjust their workload, such as spreading their courses over additional terms, even if it means taking longer to complete the program.

Resource Barriers: Based on the nature of the curriculum and the timeframe provided, Carleton and McGill appear to offer fewer hands-on project opportunities, and Western provides limited explicit details about academic and technical support for interdisciplinary settings in their program descriptions. While this does not confirm the absence of such support, it suggests a potential gap in how these aspects are communicated to prospective students. Similarly, interdisciplinary opportunities were not explicitly highlighted in the descriptions for Carleton and McGill. This suggests a possible misalignment between the ideal goals of these programs and the resources described in their materials, raising concerns about whether sufficient emphasis is placed on these critical areas. However, it is important to note that these observations are based on the publicly available information, and further investigation would be necessary to confirm the adequacy of resources and support in these programs.

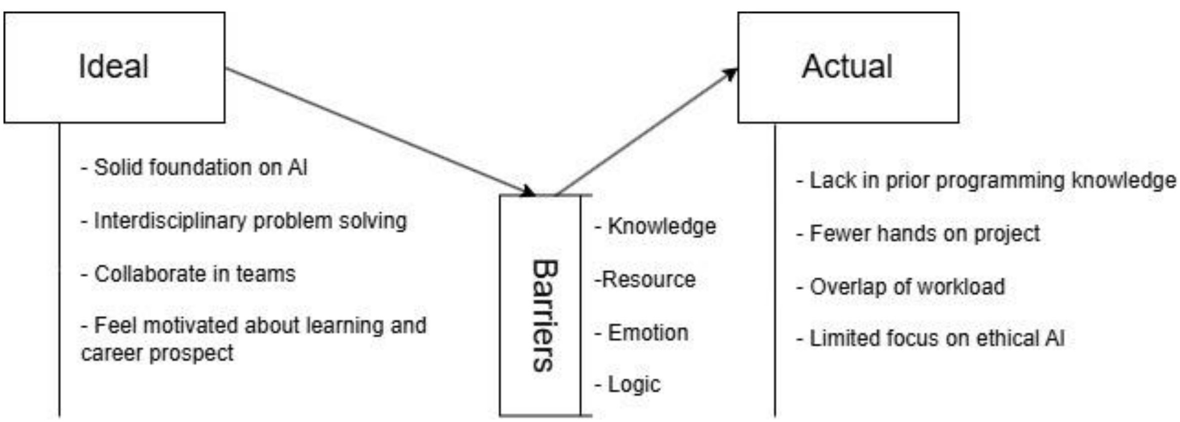

Figure 4. Identified Implementation barriers for task components (Ideal vs Actual) of the students.

4.2 Synthesis of Results and Previous Research

Recent studies underscore the significance of embedding AI into engineering curricula [25]. For Canadian perspective, the Canadian Engineering Accreditation Board (CEAB) is responsible for evaluating and accrediting undergraduate engineering programs offered at Canadian institutions to ensure they meet and establish academic standards [18]. Here, in total of 12 GAs set by CEAB serve as benchmarks for evaluating the outcomes of undergraduate engineering programs. As from the manual [18], in 2022 it underwent a refinement with the “design” graduate attribute (attribute 4) to align the students with evolving technological and societal challenges that require engineers to adopt more sustainable, ethical, and interdisciplinary design approaches to address real-world problems. In the same way, such integration of AI into the curricula could facilitate other graduate attribute to the students as well, including problem analysis (attribute 2), the effective use of engineering tools (attribute 5), impact of engineering on society (attribute 9), lifelong-learning (attribute 12), among others directly. The BESc in AISE (non-accredited) programs at Western University provide a forward-looking model for integrating AI into traditional engineering disciplines. Achieving CEAB accreditation in the future would enhance their credibility, align them with national standards, and ensure graduates are better positioned for professional licensure, thus bridging the gap between innovation and industry requirements.

Researchers found a gap and failure to adequately integrate creativity, ethical reasoning, interpersonal skills into AI [25]. Hence, integrating ethical AI training into the curriculum would not only align programs with these attributes but also prepare students to tackle complex societal challenges. For example, courses or modules on “AI ethics and sustainability” could be introduced as mandatory components to foster awareness and responsibility among graduates particularly on AI.

Prior research studies suggest the reinforcement on supplementary materials and extra guidance for students from traditional engineering major for proper understanding [26]. Not only the students, instructors also face challenges in defining AI use cases and assessing student competencies in some cases [27] [4]. As now we can observe the rapid adoption of Generative AI (GenAI) tools (ChatGPT, Copilot, Gemini etc.) among students, we believe that instructors have to rethink what students should learn, how they should learn and how their learning should be assessed. In recent time, initiatives from universities for faculty development are being taken focusing on AI education. For example, Stanford University offers "Defining AI for Educators Workshop Kit" designed to introduce educators to generative AI tools and encourage deeper engagement with AI in teaching [28]. The Association of American Colleges and Universities (AAC&U) has also initiated a series of workshops titled "Teaching with AI," aimed at preparing faculty for the evolving educational landscape shaped by AI [29]. Even industries like OpenAI, in collaboration with Common Sense Media, has launched a free training course to help teachers understand AI and its applications in education [30]. In Canada, Education department of Concordia University organized a symposium named ‘Summer Institute 2024” for educators and instructional designers, where it explores the impacts of AI on the analysis, design, development, delivery and implementation of instruction [31]. Also, at the time of submitting this paper, Center for Teaching and Learning (CTL) at Concordia University organized Winterfest 2025 showcasing innovative ways its faculty and staff are integrating GenAI into education from curriculum design to practical applications like accessibility and personalized learning [32]. Universities and relevant authorities should also ensure equitable access to AI tools, hardware and connectivity for underprivileged students as suggested in [15]. Future modifications on these programs should align the consideration of these factors.

In this study, we assessed the effectiveness of AI-infused engineering programs offered by four Canadian universities using a comprehensive framework named TASKS. The framework considered several key dimensions, including students' affect (emotions and motivations), workload and stress analysis based on the coursework, prior knowledge, and the skills these programs aim to develop. The analysis provided valuable preliminary insights into the design and outcomes of these programs.

However, as this is a work-in-progress study, we acknowledge certain limitations. At this stage, it was not possible to directly engage with students through interviews or surveys to validate and triangulate the findings. To further assess the impact of AI-infused curricula, understanding student perceptions is crucial. While this study primarily focuses on curriculum structure, future research should incorporate direct student feedback through surveys and interviews.

In the near future, we aim to address this limitation by conducting interviews and surveys with students enrolled in these programs inspired by the studies conducted at Oregon State University [33] and Harvard University [34]. If direct data collection is not possible, performing a content analysis [35] of existing literature to synthesize findings on student experiences with AI could be a feasible alternative. Additionally, conducting a meta-analysis of quantitative studies to statistically assess the impact of AI integration on student learning outcomes, challenges they face and perceptions can be explored too [36]. This additional analysis will help validate our current findings and offer a more comprehensive view of the programs' effectiveness. Future research can also explore the long-term impact of AI in engineering curricula on students' career readiness, possibly in their job placements, industry preparedness or in their postgraduate studies. By incorporating all these aspects, we hope to strengthen the robustness of the analysis and its implications for the design of AI-infused engineering curricula.

5 Conclusion

This study provides a comprehensive analysis of AI-infused undergraduate engineering programs offered by four Canadian universities, exploring their curriculum structures, program goals, and alignment with the Canadian Engineering Accreditation Board (CEAB) graduate attributes. By employing the TASKS framework, the paper identifies key implementation barriers, such as knowledge, resource, emotional, and logical gaps, that hinder the optimal integration of AI in these programs.

The findings reveal that while these programs equip students with foundational and applied AI knowledge, gaps remain in interdisciplinary exposure, ethical AI training, and support for diverse student needs. Addressing these barriers through strategic curriculum design, enhanced interdisciplinary collaboration, and targeted faculty development can create robust educational models that prepare graduates for the challenges of Industry 5.0. This work serves as a foundation for future research, including direct student feedback and the application of the TASKS framework to improve program outcomes and societal relevance.

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