CS 7180: Generative AI

Graduate Course, Khoury College of Computer Sciences
Northeastern University, Vancouver & Seattle Campuses
Spring 2025 Semester

Northeastern University Vancouver acknowledges that the land on which we gather is the unceded territory of the Coast Salish Peoples, including the territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh(Squamish), and Səl̓ílwətaɬ/Selilwitulh (Tsleil-Waututh) Nations.

Northeastern University Seattle acknowledges the living history and ancestral and unceded lands of the Coast Salish People, including the dxʷdəwʔabš (Duwamish), dxʷsəq̓ʷəbš (Suquamish), sduhubš (Snohomish), bəqəlšuɬ (Muckleshoot), and dxʷlilap (Tulalip) nations. We honor with gratitude the land itself and commit to continued activism and advocacy of the Indigenous nations people and allies in Washington state and beyond.

Class Hours:	Tuesday 3:15PM - 5:15PM
Class Location:	Vancouver: Room 1425 / Seattle: 225 Terry Ave 416
Instructor:	Dr. Ryan Rad r.rad@northeastern.edu Office Hour: Monday 2:00PM - 3:00PM
TAs	Jamie Zhou zhou.jiao@northeastern.edu Office Hour: TBD

1. Course Description

Generative AI is revolutionizing industries by enabling machines to produce human-like text and solve complex tasks. This course provides students with both the theoretical foundation and practical skills to understand, analyze, and apply generative AI techniques effectively. The course begins with foundational concepts in AI and machine learning, progresses to advanced natural language processing (NLP), transformer models, and large language models (LLMs), and concludes with cutting-edge techniques like prompt engineering, domain-specific adaptations, and retrieval-augmented generation (RAG). Students will gain the knowledge and skills needed to apply generative AI to real-world problems while critically engaging with its ethical implications and future trends.

1.2 Course Objectives

By the end of this course, students will be able to:

1. **Understand** the fundamental concepts and architectures behind generative AI, including neural networks, transformers, and large language models (LLMs).
2. **Analyze** and compare various generative AI techniques, such as prompt engineering, fine-tuning, Reinforcement Learning by Human Feedback (RLHF), and retrieval-augmented generation (RAG).
3. **Implement** generative AI models using frameworks and apply them to solve real-world text-based problems.
4. **Adapt** pre-trained LLMs for domain-specific tasks through fine-tuning and transfer learning.
5. **Evaluate** the ethical challenges and societal impacts of generative AI, including responsible usage and emerging concerns.

2 Course Structure

The course is structured into **4 modules**, each designed to build a progressive understanding of generative AI, from foundational concepts to advanced applications and future directions.

Module 1: Foundations of AI and ML (2 sessions)
Establish a strong foundation in AI and Machine Learning concepts, focusing on deep learning fundamentals.

- **Session 1:** Introduction to AI and Machine Learning
- **Session 2:** Deep Learning Fundamentals

Module 2: Foundations of NLP and Sequential Modeling (2 sessions)
Introduce Natural Language Processing (NLP) fundamentals and sequential modeling techniques for modern text processing and generation.

- **Session 3:** Fundamentals of NLP, Embeddings and Vector Spaces
- **Session 4:** Sequential Modeling, from RNN to Transformer

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Module 3: LLMs and Their Applications (4 sessions)
Explore advanced techniques for leveraging large language models (LLMs), including domain-specific adaptations, retrieval-augmented generation, and fine-tuning.

- **Session 5:** Text Generation and Large Language Models (LLMs)
- **Session 6:** Prompt Engineering
- **Session 7:** Domain-Specific LLMs and Retrieval-Augmented Generation (RAG)
- **Session 8:** Domain-Specific LLM Fine-Tuning and RLHF

Module 4: AI Agents, MLOps, and Future Directions (2 sessions)
Apply generative AI knowledge to design AI agents and explore MLOps practices, ethical considerations, and future trends in generative AI.

- **Session 10:** Generative AI Agents
- **Session 11:** MLOps for Gen AI and Future Directions

2.1 Weekly Schedule*

Week	Date	Topics	Notes
1	Jan 07	• Introduction to AI and Machine Learning	Bring a smile & tons of energy! HW1 (mini) released
2	Jan 14	• Deep Learning Fundamentals	HW 1 (mini) due Jan 17 HW 2 released
3 Seattle	Jan 21	• Fundamentals of NLP, Embeddings and Vector Spaces	
4	Jan 28	• Sequential Modeling from RNN to Transformer	HW 2 due Jan 31 HW 3 released
5	Feb 04	• (Large) Language Models	Course Feedback due Feb 07
6	Feb 11	• Prompt Engineering	HW 3 due Feb 14 HW 4 released
7 Seattle	Feb 18	• Retrieval-Augmented Generation (RAG)	
8	Feb 25	• Fine-Tuning and RLHF	HW 4 due Feb 28
9	Mar 04	Spring Break – No Class	Enjoy your break!
10	Mar 11	• Selected Topics	Group Seminars - Session 1 Project Proposal due Mar 11
11	Mar 18	• Selected Topics	Group Seminars - Session 2 Project Proposal due Mar 18
12 Seattle	Mar 25	• Generative AI Agents	
13	Apr 01	• MLOps for Gen AI	
14	Apr 08	• Project Presentation • Course Wrap-Up and Future Directions	Project Presentation (M2) due Apr 08
15	Apr 15	• Finalizing Projects – No Class	Final Deliverables (M3) due Apr 18

* This schedule is subject to change as we navigate through the term. The latest schedule can be found on Canvas.

2.1 Pre-class Work

This course, as well as most other MSCS courses at Khoury College, will be taught using a pedagogical technique known as the Hybrid classroom. In this approach, there will be a combination of asynchronous (online) materials that you will be expected to study on your own, and synchronous (in-class) activities and discussions, in which important concepts will be reviewed and students are expected to participate at scheduled times. The asynchronous component will be the primary means by which the course materials are delivered. And then during class, you will apply your understanding of these core concepts through carefully-chosen problems and activities, which will enable you to solidify your knowledge.

Our classrooms require much more focus and preparation time, for both the instructor and the students. After all, it is much easier for the instructor to read a set of pre-prepared slides and for the students to passively observe and listen. But on our campus, we will devote our class time to the computational thinking process: resolving obstacles, developing conceptual understanding, communicating solutions supported by evidence, and creating efficient algorithms that solve our problem. Through this process, you will better develop your confidence, creativity, and critical-thinking skills, preparing you to become *computer scientists* (not just programmers).

In order for this course to be a meaningful learning experience, you will need to come to each class well-prepared, with all assigned readings and videos complete, as well as your individual quiz finished to the best of your ability. This emphasis on pre-class work is the reason why our class meets for only 2 hours each week, compared to other four-credit courses at Northeastern that meet for 3.25 hours each week. If you do not complete the pre-class work, you will have a hard time following the in-class activities, which will make it that much harder for you to successfully complete the Problem Sets, Programming Projects, and Course Syntheses.

I have designed this course so that you will be spending approximately 12 to 20 hours per week on all activities relating to this course (i.e., pre-class work, attending class, all assessments).

2.2 In-class Work

If you join class in person, you are strongly encouraged to bring your laptop or phone to class so that you can participate in the activities. Most lectures will feature interactive activities and/or polls that support the material being presented. You must be present in class to complete the activity or take the poll (participating in an online activity while not attending the synchronous session will be considered academic dishonesty and will be treated harshly). Each instructor may have a different style for assigning participation grades, but historical grading information suggests that each style results in a similar overall grade distribution. Participation grades will be posted on Canvas, and regularly updated.

Students are expected to attend classes regularly, take quizzes, and submit assignments and other work at the times specified by the instructor. Students who are absent repeatedly from class or labs will be evaluated by faculty responsible for the course to ascertain their ability to achieve the course objectives and to continue in the course. Instructors may include, as part of the semester's grades, marks for the quality and quantity of the student's participation in class.

PLEASE DON'T BE LATE. You are an essential part of the class. Your participation is an essential part of the class. If you are late, please be courteous to others when entering.

BE PRESENT WHEN YOU ARE ATTENDING CLASS. Please do not distract yourself from the class by doing other activities such as phone calls, email, facebook, chat/IM/texting, games, web surfing – unless it has a direct bearing on the course. Then, by all means, surf away!

3 Course Assessment

There are several methods of assessment in this course.

- **Reflection** **3%**
  - 2 course feedback surveys, each 0.5%
  - 2 short course reflection essays, each 1%
- **Homework Assignments** **50%**
  - 4 Individual Assignments, HW1 is 8%, HW2-4 are 14% each
- **Seminar** **9%**
  - Team-based, selected topic
- **Final Team Project** **38% (+2% Bonus)**
  - Milestone 1: Project Proposal – 3%
  - Milestone 2: Project Presentation – 4%
  - Milestone 3: Project Final Deliverable - 31%
  - Capstone Showcase Poster – Bonus up to 2%

Note: Most assignments and deliverables will be due on Fridays at 7pm (PT).

3.1 Assessment Description

- **Homework Assignments - 50% (1 x 8% + 3 x 14%)**
  These assignments consist of multi-part questions based on key concepts and techniques introduced during class. All assignments are to be completed individually and may include programming tasks that reinforce generative AI concepts such as fine-tuning models or implementing foundational AI techniques.

- **Reflection - 3% (2 x 1.5%)**
  There will be two course reflection surveys and essays, each combo will be worth 1.5%

- **Seminar - 10%**
  A team-based seminar where each group selects a topic complementary to the course content. Teams will explore these topics in more depth, present their findings, and lead a mini-tutorial in class.

- **Final Team Project - 37%** (three milestones)
  The project involves three milestones:
    - **Milestone 1 (3%)**: Project Proposal – Submit a detailed plan outlining the project objectives, methodology, and expected outcomes.
    - **Milestone 2 (4%)**: Project Presentation – Present your project progress and findings.
    - **Milestone 3 (30%)**: Project Final Deliverable – Submit a comprehensive report detailing your project results, methodology, and conclusions.

3.2 Late/Makeup Policy

All tasks and assignments have a specific due date and time. **Your work is late if it is not turned in by the deadline.** In-class activities and quizzes and final project will not be accepted late. **Homework assignment submissions will be accepted only up to 48 hours after the deadline with 5% penalty every 6 hours (late time will be rounded up to the next level)**. For example, if an on-time submission would have received a grade of 90 points, the same assignment submitted 7 hours late would receive 81 points (90 x 0.90). **Assignments submitted more than 48 hours late will receive a zero.**

Make-up assignments (team or individual) will not be given. Sometimes life gets in the way of schedules. Sickness or other unplanned or extraordinary events happen and will be dealt with individually. It is your responsibility to ensure your situation is known to the instructor as soon as reasonably possible. You are accountable for being heard, which means you need to ensure that the instructor heard you.
While "life happens," poor planning by you does not count. And definitely do not wait to discuss gray areas. For example, an interview opportunity arises (good!): you should not wait until the day before the assignment is due to let us know that you could not complete the assignment because you had to prepare for the interview. That would be considered poor planning. Good planning would be to alert the TA or Instructor that you got the interview and, while you hope to finish the assignment, there is a concern. Then when you don't finish on time, it's clear that you planned your time and that will be taken into consideration. These "good planning" situations will be considered individually.

3.3 Grade Calculations

Grades will be calculated on an absolute basis: there will be no overall curving. The mapping of raw point totals to letter grades is given below. Please note that these grade boundaries may move slightly at the discretion of the instructor, but the grade boundary for A is unlikely to change.

93.00–100.00	A
90.00–92.99	A-
86.00–89.99	B+
82.00–85.99	B
77.00–81.99	B-
73.00–76.99	C+
69.00–72.99	C
65.00–68.99	C-
0.00–64.99	F

3.4 Grading Appeal

We strive to provide as much details as possible and model solutions will made available when possible. If you have concerns regarding the grading of your work and would like to respectfully ask us to regrade your work, please let us know *right away* by opening a regrade request by post (private message, including TAs and Professor) on Piazza or via email. All regrade requests must be submitted within 7 days from your receipt of the graded work. If your regrade request is closed and you feel that the response was not satisfactory, you may appeal to the instructor via one single email detailing all your reasons within 48 hours of the initial decision.

I encourage you to spend your time and energy where it serves you the most which will be learning from past mistakes and self-improvement. While we reserve your right to ask for a re-grade, we find debating grades an incredible drain on course staff time and energy and prevents us from serving students well and focusing on most important aspects of the course.

4 Course Materials

There is an associated Canvas page for this course. I will use it to post weekly reading assignments, lecture materials, labs, feedback, and grades.

4.1 Textbook: The required reading for this course is provided on the course website. Students are expected to read each week's materials as well as view any of the supplemental videos before attempting that week's assignments. Trying to do the assignments without reading the posted material or watching the videos will make the assignments much harder than they are designed to be. For some of you, it will be necessary for you to review the module's material more than once to truly understand the material.

4.2 Programming Language: In this course, we will work with a language that is most widely used in Machine Learning & AI, which is Python.