Northeastern
College of Engineering

Applied Deep Learning and Generative Models in Healthcare
Spring 2026

Course Information
Course Title: Applied Deep Learning and Generative Models in Healthcare
Course Number: CSYE 7374
Term and Year: Spring 2026
Credit Hour: 4 SH
CRN: 41498
Course Format: Online (Virtual)

Instructor Information
Full Name: Mahmoud Ebrahimkhani (Matt Ebrahim)
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Office Hours: Saturdays from 11:00 AM to 12:00 PM ET

Instructor Biography
Dr. Ebrahim is a Senior Data Scientist at Formation Bio, where he builds large-language-model and knowledge-graph systems that accelerate drug development with transparent, explainable insights. He earned a B.S. in Electrical Engineering and an M.S. and Ph.D. in Biomedical Engineering from Stony Brook University. His doctoral work pioneered machine-learning approaches for terahertz time-domain spectroscopy and imaging, demonstrating deep-learning–based detection of histological markers in burn injuries. After completing his Ph.D., Matt joined the Department of Radiology at Northwestern University as a postdoctoral research associate, advancing the use of generative adversarial networks and diffusion models to synthesize rare-disease MRI data. He then moved to industry as a Machine Learning Scientist at 1910 Genetics, where he designed end-to-end generative-AI pipelines for drug-discovery chemistry.

Course Prerequisites
Solid grasp of core deep-learning concepts (e.g., gradient descent, back-propagation, multilayer perceptrons)

Proficiency in Python for data science and model development

Prior coursework in statistics and machine learning (recommended)

Course Description
This course provides a comprehensive introduction to generative AI techniques and their applications in healthcare. Students will explore cutting-edge methods spanning from foundational deep learning architectures to state-of-the-art generative models, with hands-on implementation experience throughout.

The course progresses through three main phases:

Foundations & Language Models (Weeks 1-5): Beginning with large language models specialized for biomedical applications (BioBERT, Med-PaLM), students will learn fine-tuning strategies, retrieval-augmented generation (RAG) for clinical knowledge retrieval, and multimodal learning approaches including CLIP and MedCLIP. Self-supervised and contrastive learning methods will provide essential background for understanding modern medical AI systems.

Computer Vision & Generative Models (Weeks 6-10): The course then covers medical image analysis fundamentals including segmentation and classification using CNNs and Vision Transformers, before diving deep into generative approaches. Students will implement GANs for medical image synthesis and master diffusion models—from DDPM theory to practical latent diffusion applications. Special emphasis on synthetic data generation for rare diseases and data augmentation strategies.

Molecular AI & Drug Discovery (Weeks 11-12): Advanced topics include protein language models (AlphaFold, ESM-2) for structure prediction and generative AI methods for drug discovery, including GFlowNets and molecular diffusion models.

Throughout the course, students will complete four hands-on assignments and a final project, gaining practical experience in designing, training, and evaluating generative AI systems for real-world healthcare challenges.

Course Learning Outcomes

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

Design and fine-tune specialized language models for biomedical applications, including domain-adapted models like BioBERT and Med-PaLM, and implement retrieval-augmented generation (RAG) systems for clinical decision support.

Implement foundational and generative computer vision models for medical imaging, progressing from CNNs and Vision Transformers for segmentation and classification to GANs and diffusion models (DDPM, latent diffusion) for synthetic medical image generation.

Build multimodal AI systems that integrate text and image modalities using architectures like CLIP and MedCLIP, and apply self-supervised and contrastive learning techniques for robust medical AI development.

Apply generative AI to molecular biology and drug discovery, including protein language models (AlphaFold, ESM-2) for structure prediction and generative methods (GFlowNets, molecular diffusion) for therapeutic design.

Create synthetic data pipelines to address data scarcity in rare disease domains, implementing advanced augmentation strategies and evaluating their impact on model performance and clinical applicability.

Design, implement, and critically evaluate end-to-end generative AI solutions for real-world healthcare challenges, demonstrating proficiency through hands-on assignments and a comprehensive final project addressing problems in medical imaging, clinical NLP, or drug discovery.

Required Tools and Course Textbooks.

Bishop, C. M. Deep Learning: Foundations and Concepts. Springer.

Chollet, F. Deep Learning with Python (2nd ed.). Manning Publications, 2021.

Tunstall, L., von Werra, L., & Wolf, T. Natural Language Processing with Transformers. O'Reilly Media, 2022.

Course Schedule/Topics Covered.

Week	Date	In Class Topic	Assignment Due
1	Jan 10	Introduction to Generative AI in Healthcare	
2	Jan 17	Large Language Models (BioBERT, Med-PaLM, fine-tuning)	
3	Jan 24	Retrieval-Augmented Generation & Clinical NLP	Assignment 1 assigned
4	Jan 31	Multimodal Learning (CLIP, MedCLIP, text-to-image)	
5	Feb 07	Self-Supervised & Contrastive Learning for Med-AI	
6	Feb 14	Segmentation & Classification (CNNs, ViTs)	Assignment 2 assigned
7	Feb 21	GANs for Medical Image Synthesis	
8	Feb 28	Diffusion Models I: DDPM & Latent Diffusion (theory)	
9	Mar 07	Diffusion Models II: Hands-on & Case Studies	Assignment 3 assigned
10	Mar 14	Synthetic Data for Rare Diseases & Data Augmentation	
11	Mar 21	Protein LMs & Structure Prediction (AlphaFold, ESM-2)	Final-project proposal due
12	Mar 28	Generative AI for Drug Discovery (GFlowNet, diffusion)	
13	Apr 04	Applied Gen-AI Workshops & Case Studies	Assignment 4 assigned
14	Apr 11	Final Project Presentations	Assignment 4 due Fri 12 • 12

Assignment Grading

Attendance: 10 %

Assignments (4 × 15 %): 60 %

Final Project: 30%

Assignment Deadlines

All assignments are due Friday at 11:59 pm ET, the night before the next class, when the following assignment will be released.

Example: If Assignment 1 is assigned in class on Saturday, 20 Sept, it is due Friday, 10 Oct at 11:59 pm ET.

A 10-percentage-point deduction is applied for each 24-hour period (or portion thereof) past the deadline, up to 72 hours. Work submitted more than three days late receives a grade of zero.

Grading Scale

Please note: This is the department's standardized grading scale. While we understand that some classes may apply a curve, faculty must establish and include a clear grading scale within the syllabus, regardless of the chosen grading method.

Percentage Range	Letter Grade	Grade Point Equivalent
95.0–100.0%	A	4.000
90.0–94.9%	A-	3.667
87.0–89.9%	B+	3.333
84.0–86.9%	B	3.000
80.0–83.9%	B-	2.667
77.0–79.9%	C+	2.333
74.0–76.9%	C	2.000
70.0–73.9%	C-	1.667
69.9% and Below	F	0.000

Incomplete Grades

An incomplete grade may be reported by the instructor when a student has failed to complete a major component of a required course, such as homework, a quiz or final examination, a term paper, or a laboratory project. Students may make up an incomplete grade by satisfying the requirements of the instructor. Be aware that instructors' policies on the granting of incomplete grades may vary and that the final decision on an incomplete grade is up to the instructor. **Instructors may deny requests for an incomplete grade.** If the missing assignment(s) have not been submitted to the instructor within 30 days from the end of the term in which the course was offered, or the agreed upon due date, the grade entered will reflect the student's grade in the course for the work completed and the missing assignments receiving no credit toward the final grade.

Attendance/Late Work Policy

Attendance Policy

In each term, students enrolled in on-ground sections are expected to be on campus and attending class beginning with the first day of classes. Students in online sections are expected to log in and participate in class beginning with the first day of classes.

Students who join a class after the first day of class during the university add period, or who are approved for late registration by the instructor and the Graduate School of Engineering, are responsible for all coursework missed prior to enrolling. In the interest of students' success, the college does not

support the arrival of students to class after the university add deadline. **Enrolled students who do not attend class during the first week of a semester risk being dropped from the course.**

In cases where an enrolled student cannot arrive to campus by the first day of class due to circumstances beyond their control, it is the student's responsibility to contact the instructor for approval and notify the Graduate School of Engineering.

Students registered in MGEN courses (INFO, CSYE, and DAMG) are allowed **a maximum of 2 absences per course,** with 3 or more absences resulting in an 'F' for that course. Course instructors are not expected to make accommodations and students are expected to inform their instructors of any absences in advance of the class. Should a student anticipate being unable to attend 3 or more classes, they should discuss their situation with their Academic Advisor to explore other types of leave and accommodations in accordance with the University's academic and global entry expectations. Students may be asked to share communications about class absences with their Academic Advisor. If a student is sick long-term or experiences a medical issue that prevents class attendance, it is strongly encouraged that they speak with their Academic Advisor (coe-gradadvising@northeastern.edu) to learn more about the Medical Leave of Absence. International students should review the Office of Global Services webpage to understand their visa compliance requirements.

Teaching Assistants (TAs) or Instructional Assistants (IAs) will be present at each class to collect student attendance.

Late Work Policy

Students must submit assignments by the deadline in the time zone noted in the syllabus. Students must communicate with the faculty prior to the deadline if they anticipate work will be submitted late. Work submitted late without prior communication with faculty will not be graded.

Course Evaluations
Student feedback on their learning experience is valuable and helps improve future courses. We encourage all students to complete the course evaluation surveys when they become available.

Surveys are distributed at both the midterm mark and the end of the term via email and are completely anonymous and confidential. Any questions about the surveys can be directed to mgen-programs@coe.northeastern.edu

MGEN Student Feedback
Students who would like to provide the MGEN unit with anonymous feedback on this particular course, Teaching Assistants, Instructional Assistants, professors, or to provide general feedback regarding their program, may do so using this survey: https://neu.co1.qualtrics.com/jfe/form/SV_cTIAbH7ZRaaw0Ki

Academic Integrity
A commitment to the principles of academic integrity is essential to the mission of Northeastern University. The promotion of independent and original scholarship ensures that students derive the most from their educational experience and their pursuit of knowledge. Academic dishonesty violates the most fundamental values of an intellectual community and undermines the achievements of the entire University.

As members of the academic community, students must become familiar with their rights and responsibilities. In each course, they are responsible for knowing the requirements and restrictions regarding research and writing, examinations of whatever kind, collaborative work, the use of study aids, the appropriateness of assistance, and other issues. Students are responsible for learning the conventions of documentation and acknowledgment of sources in their fields. Northeastern University expects students to complete all examinations, tests, papers, creative projects, and assignments of any kind according to the highest ethical standards, as set forth either explicitly or implicitly in this Code or by the direction of instructors.

The following is a broad overview, but not an all-encompassing definition, of what constitutes a violation of academic integrity:

Cheating: The University defines cheating as using or attempting to use unauthorized materials, information, or study aids in any academic exercise. When completing any academic assignment, a student shall rely on their own mastery of the subject.

Fabrication: The University defines fabrication as falsification, misrepresentation, or invention of any information, data, or citation in an academic exercise.

Plagiarism: The University defines plagiarism as using as one's own the words, ideas, data, code, or other original academic material of another without providing proper citation or attribution. Plagiarism can apply to any assignment, either final or drafted copies, and it can occur either accidentally or deliberately. Claiming that one has "forgotten" to document ideas or material taken from another source does not exempt one from plagiarizing.

Unauthorized Collaboration: The University defines unauthorized collaboration as instances when students submit individual academic works that are substantially similar to one another. While several students may have the same source material, any analysis, interpretation, or reporting of data required by an assignment must be each individual's independent work unless the instructor has explicitly granted permission for group work.

Participation in Academically Dishonest Activities: The University defines participation in academically dishonest activities as any action taken by a student with the intention of gaining an unfair advantage over other students.

Facilitating Academic Dishonesty: The University defines facilitating academic dishonesty as intentionally or knowingly helping or contributing to the violation of any provision of this policy.

Please visit https://osccr.sites.northeastern.edu/academic-integrity-policy/ to access the full academic integrity policy.

University Health and Counseling Services
As a student enrolled in this course, you are fully responsible for assignments, work, and course materials as outlined in this syllabus and in the classroom. Over the course of the semester if you experience any health issues, please contact UHCS.

For more information, visit https://www.northeastern.edu/uhcs.

Student Accommodations/Disability Access Services (DAS)

Northeastern University and Disability Access Services (DAS) are committed to providing disability services that enable students who qualify under Section 504 of the REHABILITATION ACT and THE AMERICANS WITH DISABILITIES ACT AMENDMENTS ACT (ADAAA) to participate fully in the activities of the university. To receive accommodations through DAS, students must provide documentation of a disability that demonstrates a current substantial limitation. Accommodations are approved based on a review of the information that is submitted and reviews are done on a case-by-case basis.

If the course is conducted in an on-ground (in-person) format, students are expected to attend class physically as scheduled. Professors are **not required to provide virtual attendance links** unless a student has documented accommodation approved by the **Disability Access Services (DAS) office** and their **Academic Advisor**. If a student requires accommodation for remote participation, they must submit a formal request through the **Disability Office** and coordinate with their **Academic Advisor** prior to the course start date.

For more information, visit https://disabilityaccessservices.sites.northeastern.edu/

Office of Global Services
As an F-1, J-1, or Study Permit student, you must meet certain obligations in order to maintain lawful nonimmigrant status. Maintaining status is necessary in order to retain eligibility for the benefits of F-1 or J-1 status, such as employment authorization and program extension, and can be crucial to a successful application for a change or adjustment of nonimmigrant status in the future. Failure to maintain your nonimmigrant status can result in serious problems with immigration and *could lead to deportation from the U.S. or Canada.*

Students must maintain on-ground presence throughout the academic term. At Northeastern, there are four different defined instructional methods: Traditional, Hybrid, Live Cast, and Online. Traditional, Hybrid, and Live Cast courses meet the Visas' on-ground presence requirements. **Online courses do not meet the Visas' on-ground presence requirements.**

Students enrolled in Summer courses should adhere to OGS guidelines on maintaining status during the Summer term.

For more information please visit, https://international.northeastern.edu/ogs/current-students/understanding-visa-requirements/guidelines-on-maintaining-status/

Library Services
The Northeastern University Library is at the hub of campus intellectual life. Resources include over 900,000 print volumes, 206,500 e-books, and 70,225 electronic journals.

For more information and for education specific resources, visit https://library.northeastern.edu
Network Campus Library Services: Northeastern University Library Global Campus Portals

24/7 Canvas Technical Help
For immediate technical support for Canvas, call 617-373-4357 or email help@northeastern.edu

Canvas Student Resources: https://canvas.northeastern.edu/student-resources/

For assistance with my Northeastern e-mail, and basic technical support:
Visit ITS at https://its.northeastern.edu
Email: help@northeastern.edu
ITS Customer Service Desk: 617-373-4357

Outreach, Engagement, Belonging

Northeastern University is committed to fostering a community of belonging, which is essential to the advancement of Northeastern University's mission of teaching and research. Our university is stronger as a result of the varied backgrounds, experiences, and perspectives that all members of our global community bring to the pursuit of knowledge. Embracing this pluralism is not the work of one office, department, or academic unit. It is a shared responsibility that spans disciplines and boundaries. By harnessing the power of our differences, we will continue to light the path to bold new ideas and life-changing discoveries.

It is my intention that students from all backgrounds and perspectives will be well served by this course, and that the diverse experiences that students bring to this class will be viewed as an asset. I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, socioeconomic background, family education level, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and belonging environment for every other member of the class. Your suggestions are encouraged and appreciated.

Please visit Belonging at Northeastern – Northeastern Provost for complete information.

Title IX
Title IX of the Education Amendments of 1972 protects individuals from sex or gender-based discrimination, including discrimination based on gender-identity, in educational programs and activities that receive federal financial assistance. Northeastern's Title IX Policy prohibits Prohibited Offenses, which are defined as sexual harassment, sexual assault, relationship or domestic violence, and stalking. The Title IX Policy applies to the entire community, including male, female, transgender students, faculty and staff. In case of an emergency, please call 911.

The Office for University Equity and Compliance (OUEC) leads Northeastern University's efforts in maintaining compliance with all federal, state, and provincial civil rights laws and prohibits discrimination within any of its programs, activities, and services. Please visit https://ouec.northeastern.edu/ for more information and for the link to file a report.