

Practical Machine Learning for Engineering Analytics (EM/ISE 538)

Spring 2026 Course Syllabus

COURSE INFORMATION

- **Course Website:** <https://moodle-courses2527.wolfware.ncsu.edu/course/view.php?id=6544>
- **Course Credit Hours:** 3
- **In-Person Meeting Time:** TuTh 1:30PM - 2:45PM; 4134 Fitts-Woolard Hall
- **Prerequisites/Corequisites:** **ISE 489:** P: ISE 135 (or equivalent) and ST 372 (or equivalent)
EM/ISE 538: Graduate Standings in Engineering or Engineering Management
- **Office Hours:** Weekly Wednesday 3:00 – 4:00 pm or by request.
<https://ncsu.zoom.us/j/9197954710?pwd=cnk0V1BMUmFIdDhwMGJueGdlcFhyQT09&omn=92545327455&jst=3>

INSTRUCTOR INFORMATION

| Name | Office | Contact | Office hours |
|-----------------------------------|----------|---|---|
| Professor: Fred Livingston, Ph.D. | FWH 4109 | fjliving@ncsu.edu 919-515-1549 (Office) | Wednesday 3pm Weekly (zoom) and by request. Night and weekends appointments are also available by request. https://calendly.com/fjliving |

COURSE DESCRIPTION

Machine learning is transforming engineering analytics by enabling predictive capabilities and insights from complex datasets. Engineers can analyze data from diverse sources to identify patterns, optimize performance, predict failures, and enhance maintenance strategies. These techniques shift traditional problem-solving approaches, supporting informed decisions and more effective solutions.

This course emphasizes practical applications through lectures, case studies, assignments, and projects that mirror real-world challenges. Students will explore supervised and unsupervised learning, classification, regression, clustering, anomaly detection, neural networks, and time-series prediction. The curriculum also covers preprocessing, feature selection, model training, and evaluation.

Hands-on projects will allow students to implement algorithms, apply tools, and evaluate results in realistic engineering contexts. By bridging theory with practice, the course provides a comprehensive understanding of how machine learning, AI, and deep learning can solve complex engineering problems and drive innovation in analytics and decision-making.

ASSESSMENT

Grading Policy

Module Assessments (Quizzes) (5) – **20 %**

- Introduction and Computational Foundation Model Evaluation
- Classical Machine Learning Models and Model Evaluation
- Tree-based Models and Feature Selection
- Introduction to Deep Learning
- Introduction to AI and Large Language Models

Programming Assignments (5) – **35 %**

- KNN Model
- Model Evaluation
- Tree-Based Models
- Neural Networks/Time-Series Prediction
- Retrieval-Augmented Generation/LLM Auto-Coding

Capstone Project *** (Team) – **35 %**

- Project Proposal & System Design -- **5%**
- ML / AI Technical Implementation – **12%**
- Experimental Design & Evaluation – **8%**
- Project Presentation and Live Demo – **10%**

Participation/Technical Engagement – **10 %**

- Attendance/Discussion
- Peer Review

- Research Literacy

*** Graduate students must include an AI element (e.g., deep learning, RAG, LLMs) and compare it against a classical ML baseline

Grading Scale

| Grade range | Grade letter equivalent |
|--------------|-------------------------|
| 98-100 | A+ |
| 94-97 | A |
| 90-93 | A- |
| 87-89 | B+ |
| 83-86 | B |
| 80-82 | B- |
| 77-79 | C+ |
| 73-76 | C |
| 70-72 | C- |
| 67-68 | D+ |
| 63-66 | D |
| 61-62 | D- |
| 60 and below | F |

COURSE POLICIES

Late Assignments – Assignments must be submitted by the due date. Late assignments are reduced 2% per day for up to 10 days. After 10 days, assignments are not accepted. No assignment may be submitted after the last day of class.

Exam – The exam in this course are closed book and notes, unless stated open book. Neither the Internet (i.e., Google, nor other people, may be consulted during an exam. Exams must be completed during the specific time in one single sitting subject to a time limit. Exam may cover anything from the readings or lectures.

Assignment Submission - Assignments must always be submitted via the Moodle assignment link and not by email.

Grades - Course and assignment grades, whether machine graded or graded by the instructor, are final and not subject to negotiation. Students may not email at the end of the term and ask for one more point to get a higher grade, as this creates an unfairness to other students. Grades are based on the university grading scale.

LEARNING OUTCOMES

- Apply the essential components of building and implementing prediction functions to solve engineering analytics problems.
 - Describe and compare machine learning methods such as regression and classification trees, identifying their strengths and limitations.
 - Explain and interpret fundamental concepts including training and test sets, overfitting, and error rates in model evaluation.
 - Analyze and summarize the complete process of building prediction functions, from data preparation to model validation.
 - Organize, manage, and evaluate machine learning projects by designing workflows, monitoring progress, and assessing results in real-world contexts.
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COURSE MATERIALS

Recommended Textbook, Videos, and Supplementary Materials

All Lecture material will be provided by Instructor and distributed through Moodle.

(Optional Textbook – Approx. \$42 USD)

Raschka, Sebastian., Liu, Yuxi (Hayden)., Mirjalili, Vahid., Dzhulgakov, Dmytro. Machine Learning with PyTorch and Scikit-Learn: Develop Machine Learning and Deep Learning Models with Python. United Kingdom: Packt Publishing, 2022. ISBN 978-1801819312

(Optional Textbook – Approx. \$52 USD)

Raschka, Sebastian. Build a Large Language Model (From Scratch). September 2024 ISBN 9781633437166

Course Discord Group:

<https://discord.gg/yXzbcqASnH>

Josh Starmer's State Quest:

Statistics, Machine Learning, and Data Science YouTube Channel

<https://www.youtube.com/@statquest>

A Visual Introduction to Machine Learning:

<http://www.r2d3.us/visual-intro-to-machine-learning-part-1/>

DISTANCE EDUCATION (EOL)

This course has been adapted to meet the growing popularity of a remote diverse team collaboration environment. This course will encourage communication with the in-seat students using Discord and peer software collaboration using Google Collab. You may group with in-seat students to complete the capstone project. All assignments will be submitted electronically and due at the same time as the in-seat students.

TECHNOLOGY REQUIREMENTS

This course includes individual machine learning assignments and group projects with project management tasks. Students will need a personal computer with administrative rights to collaborate outside of class.

COURSE OUTLINE

The course will include lectures, demonstrations, in-class assignments, programming assignments, and projects. Please make sure to bring your personal computers to class so you can follow along with the instructor. Additionally, there will be guest seminars on emerging topics of AI throughout the semester. Towards the end of the semester, class time may be used for project presentations, coding, and extended office hours.

Module 1: Foundations of Machine Learning & Computational Practice (3 Weeks)

Focus: ML workflow, tools, and engineering mindset

- Course overview, expectations, and ML problem framing
 - Introduction to Machine Learning for engineering applications
 - Python scientific computing stack (NumPy, pandas, matplotlib)
 - ML development environments and visualization tools (VS Code, Google Colab, Streamlit, Plotly)
 - Introduction to supervised learning
 - k-Nearest Neighbors (kNN): intuition, distance metrics, and limitations
 - Data preprocessing pipelines using scikit-learn
 - Model persistence: saving and loading trained models
 - Discussion: What makes an ML solution “engineering-ready”?
 - Research literacy: Reading and interpreting a simple ML benchmark paper
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Module 2: Classical Machine Learning & Model Evaluation (3 Weeks)

Focus: Model selection, validation, and performance reasoning

- Train/validation/test splits and cross-validation strategies
 - Model selection and hyperparameter tuning
 - Evaluation metrics for classification and regression
 - Regression models (linear, polynomial, regularized methods)
 - Unsupervised learning: clustering (k-means, hierarchical)
 - Dimensionality reduction: Principal Component Analysis (PCA)
 - Imbalanced classification and resampling strategies (SMOTE)
 - Peer review: Evaluate a classmate’s model choice and metric selection
 - Discussion: When is accuracy misleading in real systems?
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Module 3: Tree-Based Models, Feature Engineering & Ensembles (2 Weeks)

Focus: Interpretability, bias–variance tradeoffs, and structured decision models

- Feature selection vs. feature extraction
 - Algorithm selection under engineering constraints
 - Decision trees: splitting criteria, depth, and pruning
 - Overfitting and underfitting in tree-based models
 - Ensemble methods: bagging, random forests, boosting
 - Model interpretability and feature importance
 - Peer review: Model explainability and feature importance critique
 - Research literacy: Reading a short paper or industry blog on ensembles
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Module 4: Deep Learning for Sequential and Structured Data (3 Weeks)

Focus: Neural networks, representation learning, and time-series modeling

- Perceptrons, tensors, and computational graphs
- Introduction to PyTorch and GPU-accelerated training
- Single-layer and multi-layer neural networks
- Loss functions, optimization, and regularization
- Tokenization and sequence representation
- Recurrent Neural Networks (RNNs)
- Long Short-Term Memory (LSTM) networks for time-series prediction
- Discussion: When does deep learning outperform classical ML—and when doesn’t it?

- Mini-project: Predictive maintenance or sequential forecasting task
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Module 5: AI Systems & Large Language Models (2 Weeks)

Focus: Modern AI pipelines, LLM integration, and deployment awareness

- Introduction to Large Language Models (LLMs)
 - LLM APIs and local inference (OpenAI, Ollama, etc.)
 - Web-based engineering data sources and APIs
 - LLM-assisted feature engineering and code generation
 - Retrieval-Augmented Generation (RAG) pipelines
 - Few-shot and in-context learning
 - Parameter-Efficient Fine-Tuning (PEFT) and deployment considerations
 - Discussion: Trust, verification, and risks of LLM-generated code
 - Research literacy: Reading and critiquing an LLM systems paper
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Module 6: Capstone Integration Project (3 Weeks)

Focus: End-to-end ML system design and communication

- System architecture design and project proposal
 - Dataset selection, modeling strategy, and evaluation plan
 - Peer review of project feasibility and scope
 - Model development, validation, and refinement
 - Final report, presentation, and live demonstration
 - Assessment emphasis:
 - Technical correctness
 - Justification of design decisions
 - Interpretation of results
 - Communication of limitations and risks
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COURSE SCHEDULE

SCHEDULE

<https://docs.google.com/spreadsheets/d/1AIDjgz60DpTuzMrlidHlxswOv8rMnP7Qz7xjAhb41C6I/edit#gid=0>

| A | B | C | D | E | F |
|------|-----------|--|---|--|--|
| Week | Date | | Topic(s) | Book Chapter(s) | Assessment(s) |
| 1 | 1/12/2028 | Module 1: Practical Machine Learning Foundations | L1. Course Introduction and Python "Hello World" L2. Python Data Types 1/13 First Day of Classes | Ch 1. pg 1 - 18 | |
| 2 | 1/19/2028 | | L3. Data Wrangling and Visualization L4. Other Development and Visualization Tools (Google Colab, Streamlit, plotly) | Ch 4. pg 105-122 | Hw 0 (assigned): Data Wrangling and Visualization |
| 3 | 1/28/2028 | Module 2: Supervised Learning, Model Evaluation, and Feature Engineering | L5. Introduction to Machine Learning Models L6. KNN Supervised Learning Models | Ch 3. pg 98-103 | Hw 1 (assigned): KNN model and data wrangling Module 1 Quiz (due 2/1) |
| 4 | 2/2/2028 | | L7. KNN Supervised Learning (Part 2) L8. Model Performance and Clustering L9. Kmean Clustering | Ch 6 pg. 171 -204 Ch 9 | |
| 5 | 2/9/2028 | | L10. SGD Regressor L11. PCA | | Hw1 (due 2/15) Hw2 (assigned): Other Models |
| 6 | 2/18/2028 | Module 3: Decision Trees, Ensembles, and Imbalanced Learning | L12. Common Feature Selection 2/17 Wellness Day | Ch 10 | Module 2 Quiz (due 2/23) |
| 7 | 2/23/2028 | | L13. Decision Trees L14. Ensemble Methods | Ch 4 pg. 122 - 137; Ch 3 pg 88 - 97 Ch 7 pg. 205-245 | Hw2 (due 3/1) Hw3 (assigned): Decision Trees and Ensemble Methods |
| 8 | 3/2/2028 | Module 4: Neural Networks, Deep Learning, and Sequential Models | L15. Perceptron L16. Single Layer Neural Networks | Ch 7 pg. 228-245 | Module 3 Quiz (due 3/8) |
| 9 | 3/9/2028 | | L17. Multi Layer Perception L18. Recurrent Neural Networks L19. LSTM | | Term Project Proposal (due 3/15) |
| 10 | 3/18/2028 | | 3/16 - 3/20 Spring Break (No Classes) | Ch 2. pg 20 - 25; Ch 12 pg 388 - 380 | Hw3 (due 3/22) Hw4 (assigned): Neural Networks |
| 11 | 3/23/2028 | Module 5: Large Language Models, APIs, and Retrieval-Augmented Generation | L20. Introduction to LLM L21. LLM Web Applications | | Module 4 Quiz (due 4/5) |
| 12 | 4/6/2028 | | L22. Web-based Data sources APIs L23. Retrieval Augmented Generation (RAG) | | Hw4 (due 4/12) Hw5 (assigned): LLM Project Midpoint Report (due 4/12) |
| 13 | 4/13/2028 | | L24. Few-Shot Learning L25. Parameter Efficient Fine-Tuning (PERF) | | |
| 14 | 4/20/2028 | Module 6: Final Project Presentations and Demo | L26. Capstone Project Presentation and Demo (Part 1) L27. Capstone Project Presentation and Demo (Part 2) | | Module 5 Quiz (due 4/19) Hw5 (due 4/26) Final Project Report and Documents (due 4/21) |
| 15 | 4/27/2028 | | L28. Capstone Project Presentation and Demo (Part 3) 4/28 Last Day of Classes | | Final Projects Peer Review (due 5/5) |
| 16 | 5/4/2028 | | 5/5 Final Examination Period (1200 - 1430 hr) | | All assignments due 5/5 1430 hr |

ARTIFICIAL INTELLIGENCE POLICY

Artificial Intelligence Tools – AI tools (e.g., ChatGPT, GitHub Copilot) may be used to support learning; however, they may not be used on quizzes, exams, or other closed assessments. Any AI use in assignments or projects must be documented, and students are expected to verify accuracy and demonstrate full understanding of the work produced. Misuse of AI will be considered a violation of the Code of Student Conduct

STUDENT RESOURCES

Academic and Student Affairs maintains a website with links for student support on campus, including academic support, community support, health and wellness, financial hardship or insecurity, and more. [Find Help on Campus.](#)

Disability resources

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the [Disability Resource Office \(DRO\)](#). For more information on NC State's policy on working with students with disabilities, please see the [Policies, Rules and Regulations page maintained by the DRO](#) and [REG 02.20.01 Academic Accommodations for Students with Disabilities](#).

Safe at NC State

At NC State, we take the health and safety of students, faculty and staff seriously. The [Office for Institutional Equity and Diversity](#) supports the university community by providing services and resources to support and guide individuals in obtaining the help they need. See the [Safe at NC State webpage](#) for resources.

Supporting Fellow Students in Distress

[Example: As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remain a healthy and safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you, either for the classmate's well-being or yours. If you feel this way, I would encourage you to report this behavior to the [NC State CARES website](#). Although you can report anonymously, it is preferred that you share your contact information so they can follow up with you personally.]

Wellness Resources

- **[WolfPack Wellness](#)** website: the university's overarching wellness site, providing information about most of the university's programs and services. Includes both a [high level](#) and a [comprehensive list](#) of programs and services.
- **[NC State Counseling Center](#)**, list of [counseling services](#), including [AcademicLiveCare](#) (counseling telehealth).
- **[College of Textiles Embedded Counselor](#)**, Michael Tuma (shared with Graduate School).
- **[TaskHuman](#)**: FREE UNLIMITED one-on-one well-being coaching they can receive through TaskHuman in the following areas: physical fitness, professional development, mental & emotional support, healthy watching & food choices, spiritual practice & guidance, personal growth & development, etc.
- **[Pack Essentials](#)**: NC State and campus partners have developed many programs to support students in need of food, housing, financial and educational security. Includes

[food and housing resources](#) (including Feed the Pack Pantry), [financial resources](#) (includes Student Emergency Fund and PACK ASSIST), [student legal services](#), and many others.

- **Campus Community Centers:** [African American Cultural Center](#), [Multicultural Student Affairs](#), [LGBTQ Pride Center](#), and [Women's Center](#).
- **Student Ombuds:** An independent, neutral, confidential, and informal office at NC State, Student Ombuds Services is here to be a personal guide for conflict management, prevention and resolution while advocating for fair processes and empowering students to successfully navigate NC State.

UNIVERSITY POLICIES

Academic Integrity and Honesty

Students are required to comply with the university policy on academic integrity found in the [Code of Student Conduct](#). Therefore, students are required to uphold the university pledge of honor and exercise honesty in completing any assignment. Please refer to the [Academic Integrity](#) web page for a detailed explanation of the University's policies on academic integrity and some of the common understandings related to those policies. Violations of academic integrity will be handled in accordance with the Student Discipline Procedures ([NCSU REG 11.35.02](#)).

For use in courses with online exchanges among students and the instructor, but NOT persons outside the course:

Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like email or web-postings, where relevant to the course. Examples include online discussions of class topics and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

Students are responsible for reviewing the NC State University PRR's which pertains to their course rights and responsibilities, including those referenced both below and above in this syllabus:

- > [Equal Opportunity and Non-Discrimination Policy Statement](#) and [Additional References](#)
- > [Code of Student Conduct](#)
- > [Grades and Grade Point Average](#)
- > [Credit-Only Courses](#)
- > [Audits](#)

Students with Disabilities

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the [Disability Resource Office](#) at Holmes Hall, Suite 304, Campus Box 7509, 919-515-7653 . For more information on NC State's policy on working with students with disabilities, please see the [Academic Accommodations for Students with Disabilities Regulation \(REG02.20.01\)](#)

Basic Needs Security

Any student who faces challenges securing their food or housing or has other severe adverse experiences and believes this may affect their performance in the course is encouraged to notify the professor if you are comfortable in doing so. Alternatively, you can contact the Division of Academic and Student Affairs to learn more about the Pack Essentials program <https://dasa.ncsu.edu/pack-essentials/>

DEPARTMENT POLICIES

The Department strives to provide an environment conducive to learning and believes strongly in the Code of Student Conduct (POL 11.35.01). The portion below, extracted from POL 11.35.01, is specific to academic misconduct:

8 ACADEMIC MISCONDUCT

All members of the University community, students, faculty and other employees, have the responsibility to report academic misconduct to the appropriate authority. Faculty members must undertake a threshold responsibility for such traditional safeguards as examination security and proctoring and should clearly communicate their academic expectations in the course syllabus. The use of the Pack Pledge, “I have neither given nor received unauthorized aid on this test or assignment,” on all syllabi, assignments, examinations, or other academic evaluations is encouraged. Similarly, faculty members should familiarize themselves with the procedures for addressing academic misconduct. The procedures for reporting academic misconduct can be found in **[NCSU REG11.35.02 - Student Discipline Procedures](#)**.

Definitions regarding academic misconduct are set forth in writing in order to give students general notice of prohibited conduct. They should be read broadly and are not designed to define academic misconduct in exhaustive terms. If a student is in doubt regarding any matter relating to the standards of academic integrity in a given course or on a given assignment, that student must consult with the faculty member responsible for the course before presenting the work.

8.1 Aiding and Abetting

Aiding and abetting others to cheat or plagiarize is as detrimental to the scholarly community as engaging in the acts themselves. Aiding and abetting others to cheat or plagiarize includes, but is not limited to, the following:

- (a) Giving unauthorized assistance to another or others during a test or evaluation;
- (b) Posing as another student in order to meet a course or graduation requirement;
- (c) Providing specific information about a recently given test, examination, or assignment to a student who thereby gains an unfair advantage in an academic evaluation;
- (d) Providing aid to another person, knowing such aid is expressly prohibited by the faculty member, in the research, preparation, creation, writing, performing, or publication of work to be submitted for academic evaluation;
- (e) Permitting one's academic work to be represented as the work of another; or

(f) Sharing or distributing academic materials, including class notes, in violation of the **UNC Policy Manual 500.2 – Patent and Copyright Policies** or **NCSU REG01.25.02 – Copyright Infringement – Policy Statement**.

8.2 Cheating

Cheating is the giving, taking, or presenting of information or material by a student that unethically or fraudulently aids oneself or another person on any work which is to be considered in the determination of a grade or the completion of academic requirements or the enhancement of that student's record or academic career. Cheating includes, but is not limited, to the following actions:

- (a) Copying from someone else's assignment, examination, or other academic exercise;
- (b) Possessing, buying, selling, removing, receiving, or using, at any time or in any manner not prescribed by the faculty member, any information related to an instrument of academic evaluation;
- (c) Using materials, equipment, or assistance in connection with an assignment, examination, or other academic exercise which have not been authorized by the faculty member, including but not limited to, notes, calculator, or other technology;
- (d) Obtaining or attempting to obtain, in a dishonest manner, any material relating to a student's academic work;
- (e) Working with another or others in completing an assignment, examination, or other academic exercise when the faculty member has required independent and unaided action;
- (f) Attempting to influence or change an academic evaluation, grade, or record by unfair means;
- (g) Permitting another individual to substitute for one's self in an academic evaluation;
- (h) Marking or submitting an examination or evaluation material in a manner designed to deceive the grading system;
- (i) Failing to comply with a specific condition of academic integrity which has been clearly announced in a particular course;
- (j) Submitting, without prior permission of the faculty member, any work by a student which has at any time been submitted in identical or similar form by that student in fulfillment of any other academic requirement at any institution;
- (k) Submitting of material in whole or part for academic evaluation that has been prepared by another individual(s);
- (l) Submitting data which have been altered or contrived in such a way as to be deliberately misleading; or
- (m) Providing false information to the University in any manner to achieve an unfair advantage, enhance one's record, or complete a requirement.

8.3 Destruction or Removal of Academic Materials

The destruction or removal of academic materials denies access to, and prevents the ability to develop the full potential of, scholarly resources. Prohibited acts under this section include, but are not limited to, the following:

- (a) Removing or attempting to remove, destroy, steal, or make inaccessible library or other academic material without authorization; or

(b) Willfully damaging the academic work or efforts of another.

8.4 Plagiarism is the use or close imitation of the language and thoughts of another and the representation of the other's work as their own. The act of submitting work for evaluation or to meet a requirement is regarded as assurance that the work is the result of the student's own thought and study, produced without assistance, and stated in that student's own words, except as quotation marks, references, or footnotes acknowledging the use of other sources. Any ideas or materials taken from another source for either written or oral use must be fully and correctly acknowledged. Submission of work used previously must first be approved by the faculty member. Plagiarism includes, but is not limited, to the following actions:

- (a) Representing the work of others as his or her own; or
- (b) Submitting written materials without proper attribution or acknowledgment of the source.