

# Machine Learning, SCS Concentration

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<https://www.ml.cmu.edu/academics/ml-concentration.html>

## Machine Learning Concentration

**This concentration is available to SCS students only.**

Machine learning and statistical methods are increasingly used in many application areas including natural language processing, speech, vision, robotics, and computational biology. The Concentration in Machine Learning allows undergraduates to learn about the core principles of this field. The Concentration requires five courses (two core courses and three electives) from the School of Computer Science (SCS) and the Department of Statistics & Data Science. The electives primarily focus on core machine learning skills that could be broadly applicable to either industry or graduate work. A CS Senior Honors Thesis or two semesters of Senior Research may be used to satisfy part of the electives requirement, which could provide excellent research experience for students interested in pursuing a PhD.

## Learning Objectives

Upon completion of this concentration, students should be able to:

- Formulate real-world problems involving data such that they can be solved by machine learning
- Implement and analyze existing learning algorithms
- Employ probability, statistics, calculus, linear algebra, and optimization in order to develop new predictive models or learning methods
- Select and apply an appropriate supervised learning algorithm for problems of different kinds, including classification, regression, structured prediction, clustering, and representation learning
- Describe the formal properties of models and algorithms for learning and explain the practical implications of those results
- Compare and contrast different paradigms for learning

## Curriculum

### Prerequisites

Students must complete the prerequisites for 10-301 or 10-315 or 07-280. To view the prerequisites for 10-301 or 07-280, please click on the respective course number under "Core Courses" below. For each prerequisite, a grade of C or higher is required.

### Course Requirements

The ML Concentration requires that students complete two core courses and their choice of three elective courses of at least 9 units each. The electives can be through a combination of coursework in Machine Learning and optionally senior research.

### Core Courses - 2 Courses:

Students must take two core courses, each being at least 9 units:

|                                                                       | Units |
|-----------------------------------------------------------------------|-------|
| 10-301 Introduction to Machine Learning                               | 12    |
| or 10-315 Introduction to Machine Learning (SCS Majors)               |       |
| or 07-280 Artificial Intelligence and Machine Learning I              |       |
| Plus one of:                                                          |       |
| 10-403 Deep Reinforcement Learning & Control                          | 12    |
| or 10-405 Machine Learning with Large Datasets (Undergraduate)        |       |
| or 10-414 Deep Learning Systems: Algorithms and Implementation        |       |
| or 10-417 Intermediate Deep Learning                                  |       |
| or 10-418 Machine Learning for Structured Data                        |       |
| or 10-422 Foundations of Learning, Game Theory, and Their Connections |       |

### Electives - 3 Courses:

Students need to take three courses from the following list, each being at least 9 units. Students may substitute one of these courses with one semester of an SCS Senior Honors Thesis or equivalent senior research credit.

|           |                                                                    |    |
|-----------|--------------------------------------------------------------------|----|
| 10-403    | Deep Reinforcement Learning & Control                              | 12 |
| or 10-703 | Deep Reinforcement Learning & Control                              |    |
| 10-405    | Machine Learning with Large Datasets (Undergraduate)               | 12 |
| or 10-605 | Machine Learning with Large Datasets                               |    |
| or 10-745 | Scalability in Machine Learning                                    |    |
| 10-414    | Deep Learning Systems: Algorithms and Implementation               | 12 |
| or 10-714 | Deep Learning Systems: Algorithms and Implementation               |    |
| 10-417    | Intermediate Deep Learning                                         | 12 |
| or 11-485 | Introduction to Deep Learning                                      |    |
| or 10-707 | Advanced Deep Learning                                             |    |
| 10-418    | Machine Learning for Structured Data                               | 12 |
| or 10-618 | Machine Learning for Structured Data                               |    |
| or 10-708 | Probabilistic Graphical Models                                     |    |
| 10-422    | Foundations of Learning, Game Theory, and Their Connections        | 12 |
| 10-423    | Generative AI                                                      | 12 |
| or 10-623 | Generative AI                                                      |    |
| 10-425    | Introduction to Convex Optimization                                | 12 |
| or 10-625 | Introduction to Convex Optimization                                |    |
| or 10-725 | Optimization for Machine Learning                                  |    |
| 10-613    | Machine Learning Ethics and Society (or 10-713)                    | 12 |
| 10-643    | Socio-technical Evaluations of Generative AI (or 10-743 or 11-805) | 12 |
| 10-735    | Responsible AI                                                     | 12 |
| 10-777    | Historical Advances in Machine Learning                            | 12 |
| 36-401    | Modern Regression                                                  | 9  |

### Important Notes:

- Regarding prerequisites, 07-280 is a substitute for 10-301. Therefore, wherever you see 10-301 listed as a prerequisite you can also use 07-280.
- To avoid excessive overlap in covered material, at most one of the core Deep Learning courses may be used to fulfill concentration course requirements: 10-417, 10-617, 11-485, 10-707. In general, students are discouraged from taking more than one of these.
- 15-281 Artificial Intelligence: Representation and Problem Solving covers several topics (i.e. reinforcement learning and Bayesian networks) that are complementary to 10-315. While not part of the ML Concentration curriculum, this course is also one to consider.
- Students should note that some of these elective courses (those at the 600-level and higher) are primarily aimed at graduate students, and so should make sure that they are adequately prepared for them before enrolling. Graduate-level cross-listings of these courses can also be used for the ML Concentration, if the student is adequately prepared for the more advanced version and the home department approves the student's registration.
- Please be aware that not all graduate-level courses in the Machine Learning Department may be used as electives. In particular, 10-606/10-607 Computational Foundations for Machine Learning may not be used as electives for the Machine Learning Concentration.

### SCS Senior Honors Thesis

The SCS Senior Honors Thesis (<http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/honors-research-thesis/>) consists of 36 units of academic credit for this work. Up to 12 units may be counted towards the ML Concentration. Students must consult with the Computer Science Department for information about the SCS Senior Honors Thesis. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

### Senior Research

Senior Research consists of 2 semesters of 10-500 Senior Research Project, totaling 24 units. Up to 12 units may be counted towards the ML Concentration.

The research must be a year-long senior project, supervised or co-supervised by a Machine Learning Core Faculty member. It is almost always conducted as two semester-long projects, and must be done in senior year.

Interested students should contact the faculty they wish to advise them to discuss the research project, before the semester in which research will take place.

Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

The student **should email the ML Minor Director a brief update (two paragraphs) on their progress at the end of the Fall semester, and will** present the work at the Meeting of the Minds (<https://www.cmu.edu/uro/MoM/>) and submit a year-end write-up to the Minor Director at the end of Senior year.

### Double Counting

At least 3 courses (each being at least 9 units) must be used for only the Machine Learning Concentration, not for any other major, minor, or concentration. (These double counting restrictions apply specifically to the Core Courses and the Electives. Prerequisites may be counted towards other majors, minors, and concentrations and do not count towards the 3 courses that must be used for only the Machine Learning Concentration.)

## Advising and Management

The ML Concentration Director will hold advising office hours leading up to registration week each semester. In addition, the ML Concentration Program Coordinator will hold regular office hours to address general questions. All office hours will be detailed on the ML Concentration website.

SCS Students interested in pursuing this concentration should contact Matt Gormley ([ml-concentration@cs.cmu.edu](mailto:ml-concentration@cs.cmu.edu) ([ml-minor@cs.cmu.edu](mailto:ml-minor@cs.cmu.edu))) for an initial advising consultation.