ST 558D
Probability & Statistics

Instructor: Dr. Anwar Hossain, Weir 238, Ext. 5135
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Prerequisite: ST 550 or consent of instructor and a basic knowledge of calculus.

Text: Probability and Statistics for Engineers and Scientists by Walpole, Myers, Myers, Ye, 8th edition, Prentice Hall.

Course Descriptions:
This course is designed to provide basic concepts of probability theory. Topics include the calculus of events, probability, random variables, distributions, moments, moment-generating function, and sampling distributions. If time permits, some statistical inference topics may also be introduced.

Goal: The goal of this course is to help you become familiar with the techniques, procedures and concepts of probability and statistics.

Objectives: (1) To learn ideas of probability
(2) To learn ways to calculate in probability based models in science and engineering
(3) To learn basic concepts and applications of statistics
(4) To learn how to construct and apply probability models in science and Engineering
(5) To learn descriptive statistics
(6) To learn inferences about population parameter(s)

Materials to be Covered:

Descriptive Statistics & Sampling procedures:
How do you estimate a probability density function? What are the measures of centrality? (Mean mode and median) What are the measures of dispersion (variance, standard deviation, maximum, range, percentiles, etc.)? How do you detect Outliers? Concepts of population and sample. What are the different sampling schemes?

Probability Definitions and Rules:
What do we need to specify probability function on events? What is a probability function? How are probabilities assigned? What are some consequences of these axioms? Additive Rules
Conditional probability
What is conditional probability? Why is it useful in probability assignments? Why are tree diagrams useful? What are some applications of conditioning?

Independence and Rules of Probability:
What is independence? Why is it useful? How does it contrast with mutual exclusion? What are the useful rules of probability? Multiplicative Rules.

Bayes Theorem or Bayes Rule:
What is the theorem of total probability? What is Bayes theorem? To what kinds of problems does it apply? How are tree diagrams useful here? Applications of probability and Bayes Rule.

Random variables and Probability distributions:
What are random variables? How is their behavior described? What are distribution and probability functions? What are their properties?

Continuous Random variables:
What is a continuous Random variable? How is it described? What is a probability density function? What are the measures of continuous random variables?

Expected Values: What are the mean, variance and standard deviation of a discrete random variable? What are the useful properties?

Joint random variables:
How is the behavior of several random variables described? What are the joint distribution functions and joint probability density functions? How are they related and how are probabilities calculated? What are the conditional probability functions?

Expected Values and properties:
How are the expected values of functions of several random variables defined? What is the covariance between two random variables? What is correlation coefficient? What is a conditional expected value? What are some important properties of conditional expectations?

Some Discrete Probability Distributions:
Uniform, Binomial and Multinomial distributions:
What are the assumptions of uniform, Binomial and multinomial distributions? What are the mean and variances of the distributions?

Hypergeometric, Negative Binomial and Geometric Distributions:
What is the Negative Binomial distribution? When is it applied? What are the mean and variances of the above distributions?

Poisson distribution & the poisson Process:
What is the Poisson distribution? When is it applied? What are the mean and variances of the above distribution?
Some continuous distributions:
What is uniform distribution? What is the exponential distribution? When are they used?
What is a gamma random variable and what are its properties? Gamma & Exponential distributions, Chi-Squared, Lognormal Distribution & Weibull Distributions.

Normal Random Variable:
What is a standard normal density? What are the mean and variance of a normal distribution?
How are probabilities calculated for normal random variables? What are some applications of the Normal Distribution? What are ways to check Normality? What is a Q-Q plot and how is it used?
Normal approximation to the Binomial.

Functions of random variables:
How can we treat functions of random variables? What is the method of distribution functions?
What is the method of transformation? Why is the sum of the random variables important? What are the limiting properties of probabilities?

Moment generating functions:
How are moments generating functions defined for continuous case? What are some common moment generating functions? What is the Central limit Theorems? How is it applied? T-distribution & F-distribution.

Estimation and hypothesis testing:
Point and interval estimates for large and small samples. Paired observations. Estimating proportion. Maximum likelihood estimation. General concepts of hypotheses. One and two tailed tests. Concept of two types of errors. Concepts of P-value. Test of hypotheses for mean(s) for large and small samples. Inference of dependence data (Paired t-tests (correlated data)), and two independent population means.

Inference for population proportion(s):
Confidence interval for population proportion and test of hypothesis for proportion P. Inferences for two population proportions.

Linear regression & Correlation:
What is a least squares method? Some discussion and assumptions. Correlation analysis and residual analysis. How do you predict a value using least square technique?

ANOVA
What is analysis of variance?
How do you make an inference for more that two population means?
**COURSE POLICY:**
Your course grade will be determined on the basis of combined scores from Homework, and tests.

**Grading** is based on the percentage of total points earned (the individual tests, homework etc. are not assigned a letter grade). You have 9 homework assignments to be submitted, a midterm exam, and a final exam. An interim midterm grade will be given based on graded work to-date. Both the MIDTERM and FINAL exams must be PROCTORED by a responsible party (principal or counselor); students must submit the name, title, and physical and email addresses of the responsible party before the last day to add classes (no exceptions). Failure to provide a proctor will result in being dropped from this class.

**Distribution of points:**

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<thead>
<tr>
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<th>Homework</th>
<th>30%</th>
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<tbody>
<tr>
<td>Midterm Exam</td>
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<td>Final Exam</td>
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<td>Total</td>
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Grading Scale (tentative): A: 90-100%; B: 80-89; C: 70-79; D: 60-69; F: < 60
The instructor reserves the right to change any part of this syllabus as he sees fit.
<table>
<thead>
<tr>
<th>COMPETENCIES FOR ENTRY-LEVEL MATHEMATICS TEACHERS</th>
<th>Addresses competency</th>
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<tbody>
<tr>
<td><strong>A. Teachers will understand and use Mathematics in Problem-Solving.</strong></td>
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<tr>
<td>(1) Teachers for grades K-8 will be able to:</td>
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<tr>
<td>(a) Use problem-solving approaches to investigate and understand mathematical content.</td>
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<td>(b) Formulate and solve problems from both mathematical and everyday situations.</td>
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<td>(c) Identify, select and use appropriate problem-solving strategies; as well as develop and apply their own strategies.</td>
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<td>(d) Verify and interpret solutions to problems.</td>
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<td>(e) Use mathematical language and symbolism to model problem situations.</td>
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<tr>
<td>(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.</td>
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<tr>
<td>(3) Teachers for grades 7-12 will be able to:</td>
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<tr>
<td>(a) Use a problem solving approach to investigate and understand mathematical concepts.</td>
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<tr>
<td>(b) Formulate and solve problems from both mathematical and everyday experiences.</td>
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<td>(c) Develop their own processes and techniques for solving problems.</td>
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<tr>
<td><strong>B. Teachers will understand and use Mathematics in Communication.</strong></td>
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<tr>
<td>(1) Teachers for grades K-8 will be able to:</td>
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<tr>
<td>(a) Identify and define mathematical concepts in a variety of situations.</td>
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<td>(b) Communicate mathematical ideas both verbally and in writing.</td>
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<td>(c) Use drawings, discussion, reading, and listening to learn and communicate mathematical ideas.</td>
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<td>(d) Use a variety of electronic media and manipulatives to explore and communicate mathematical concepts and problem solutions.</td>
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<td>(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.</td>
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<tr>
<td>(3) Teachers for grades 7-12 will be able to:</td>
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<tr>
<td>(a) Develop skills in both written and oral communication of mathematical concepts.</td>
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<td>(b) Learn to communicate effectively at various levels of formality and with people who have differing levels of mathematical understanding.</td>
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<td><strong>C. Teachers will understand and Use Mathematics in Reasoning.</strong></td>
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<td>(1) Teachers for grades K-8 will be able to:</td>
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<td>(a) Describe logical conclusions.</td>
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<td>(b) Use information sources, models and known facts to explain mathematical thinking.</td>
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<tr>
<td>(c) Make and evaluate mathematical conjectures and validate their own mathematical thinking.</td>
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<td>(d) Recognize and construct logical arguments for mathematical statements, concepts, and principles.</td>
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(e) Apply a variety of reasoning processes to include deductive and inductive reasoning.

(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:
   (a) Recognize patterns, make and refine conjectures and definitions, and construct both formal and heuristic proofs.
   (b) Judge the validity of mathematical arguments.
   (c) Formulate counterexamples.

D. Teachers will understand and use Mathematical Connections.

   (1) Teachers for grades K-8 will be able to:
       (a) Show an understanding of the interrelationships within mathematics.
       (b) Connect mathematics to other disciplines and everyday situations.

   (2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

   (3) Teachers for grades 7-12 will be able to:
       (a) Develop an understanding of the interrelationships within mathematics and an appreciation of its unity.
       (b) Understand and appreciate the power of mathematical language and symbolism in the development of mathematical concepts.
       (c) Explore the connections between mathematics and other disciplines.
       (d) Apply mathematics learned in one context to other contexts.

E. Teachers will understand and use numbers, and their relationships, systems and theory.

   (1) Teachers for grades K-8 will be able to:
       (a) Construct number meanings through everyday experiences and the use of physical materials.
       (b) Understand prenumeration concepts.
       (c) Describe and compare ancient and modern numeration systems by relating counting, grouping, and place value concepts.
       (d) Develop number sense.
       (e) Identify different sets of numbers in the real number system.
       (f) Understand representations of numbers, including mixed numbers, fractions, decimals, and scientific notation.
       (g) Demonstrate ability to use models to explore and explain relationships among fractions, decimals, percents, ratios, and proportions.
       (h) Use the relations of equality and inequality.

   (2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

   (3) Teachers for grades 7-12 will be able to: Explore and discuss the properties, relations, and extensions of the real and complex numbers.

F. Teachers will understand and use computation and estimation.

   (1) Teachers for grades K-8 will be able to:
(a) Model, explain, and develop proficiency with the basic number facts and algorithms, including addition, subtraction, multiplication and division.

(b) Recognize alternative algorithms for the four basic operations.

(c) Select and use computation techniques appropriate to specific problems and determine the reasonableness of solutions.

(d) Use estimation strategies.

(e) Recognize when estimates are appropriate.

(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

(a) Understand and apply numerical computational and estimation techniques and extend them to symbolic expressions.

(b) Use estimation to assess the reasonableness of solutions.

G. Teachers will have a foundation in geometric concepts.

(1) Teachers for grades K-8 will be able to:

(a) Describe, model, draw and classify geometric figures.

(b) Investigate, predict, and describe the results of combining, subdividing and changing shapes.

(c) Develop spatial sense and relationships.

(d) Relate geometric and measurement ideas.

(e) Use geometric concepts and relationships to describe and model mathematical ideas and relationships to the world.

(f) Solve simple problems in two- and three-dimensional geometry involving parallelism, perpendicularity, congruence, similarity, translation, reflection, rotation, symmetry, and incidence.

(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

(a) Understand the role of axiomatic systems in geometry.

(b) Develop both synthetic and algebraic geometric concepts using coordinates and vectors.

(c) Use geometry as a source of mathematical models for a variety of applications.

(d) Employ geometric reasoning as a problem solving strategy.

(e) Model features of the real world using different geometries.

H. Teachers will understand and use measurement.

(1) Teachers for grades K-8 will be able to:

(a) Determine what needs to be measured, select an appropriate unit of measurement, and then select an appropriate tool with which to measure.

(b) Use standard and nonstandard units for measurement to an appropriate degree of accuracy.

(c) Use estimation, informal procedures, and formulas to solve problems involving linear measures, area, volume, mass, and temperature by using both traditional and metric systems.
(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

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<td>(a) Identify and use the appropriate units, tools of measurement, and degree of accuracy required in particular problems, making calculations of relative error as necessary.</td>
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<td>(b) Apply measurement as a tool in other disciplines</td>
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I. Teachers will understand and use statistics and probability.

(1) Teachers for grades K-8 will be able to:

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<td>(a) Collect data from real world experiences or surveys, organize and display data using various charts/graphs manually and by using appropriate technology, analyze and interpret the data, and write convincing arguments based on the data.</td>
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<td>(b) Solve elementary statistical problems relating to measures of central tendency, measures of dispersion, regression equations, and non-linear regression.</td>
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<td>(c) Critically examine and analyze data for reliability and validity.</td>
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<td>(d) Demonstrate an understanding of randomness by conducting sampling experiments.</td>
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<td>(e) Find experimental and theoretical discrete probabilities using sample spaces, tree diagrams, and other representations.</td>
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<td>(f) Plan and conduct simulations to determine experimental probabilities.</td>
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<td>(g) Compute the mathematical expectation of simple games and lotteries.</td>
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<td>(h) Solve simple problems involving probability, inference, and the testing of hypotheses.</td>
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<td>(i) Use simple combinations and permutations to solve counting problems.</td>
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(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

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<tr>
<td>(a) Understand measures of central tendency, variability, and correlation.</td>
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<tr>
<td>(b) Collect, display, analyze, and interpret sample data in a variety of situations.</td>
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<tr>
<td>(c) Investigate the role of estimation and probability in statistical analysis.</td>
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<tr>
<td>(d) Use experimental and theoretical probabilities to formulate and solve problems.</td>
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<td>(e) Develop strategies for reasoning and making decisions based on uncertainty.</td>
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<tr>
<td>(f) Explore the probabilistic nature of statistical analyses including hypothesis testing, correlation, analysis of variance, and nonparametric methods.</td>
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J. Teachers will understand and use patterns and functions.

(1) Teachers for grades K-8 will be able to:

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<tr>
<td>(a) Recognize, describe, extend, and create a wide variety of patterns.</td>
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<td>(b) Represent relationships with manipulatives, tables, graphs, verbal and written statements, and formulas.</td>
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(c) Describe what a function means both intuitively and using formal mathematical language.

(d) Demonstrate a basic understanding of classes of functions and their properties; e.g. linear, exponential, polynomial, and periodic.

(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

(a) Use multiple representations of functions, including symbolic expressions, verbal descriptions, tables, and graphs, and relate one representation to another.

(b) Use the language of functions to describe and model change.

(c) Use the concept of function in the study of mathematics and other disciplines.

K. Teachers will understand and apply algebraic concepts.

(1) Teachers for grades K-8 will be able to:

(a) Explore and use variables and open sentences to express mathematical relationships.

(b) Solve real world problems involving linear and quadratic equations and inequalities by using traditional techniques and graphing methods that use technology.

(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

(a) Understand and apply the major concepts of linear and abstract algebra.

(b) Use theoretical results to understand tangible situations

L. Teachers will understand and apply concepts of calculus.

(1) Not required of teachers for grades K-8.

(2) Teachers for grade 5-9 will be able to:

(a) Recognize particular types of change such as linear, quadratic and exponential.

(b) Use graphs, diagrams, charts, physical models, and graphing technology to explore the notions of limit, differentiation, and integration, and interpret the relationships among them.

(c) Construct infinite sequences and series, relating them to non-terminating decimals and the approximation of functions.

(d) Solve real world problems involving average and instantaneous rates of change, area, volume, and curve length, and relate those to differentiation and integration.

(3) Teachers for grades 7-12 will be able to:

(a) Investigate the phenomenon of change as a limiting process.

(b) Explore intuitively and in depth the concepts of limit, continuity, differentiation, and integration.

(c) Demonstrate an understanding of the underlying theory of analysis.

(d) Use properties and techniques of calculus to model phenomena in diverse settings.

M. Teachers will understand and apply discrete processes.
(1) Not required of teachers for grades K-8.

(2) Not required of teachers for grades 5-9.

(3) Teachers for grades 7-12 will be able to: Understand concepts and applications of discrete mathematics, such as graph theory, recurrence relations, linear programming, difference equations, and combinatorics.

N. Teachers will understand the use of technology.

(1) Teachers for grades K-8 will be able to:

(a) Use calculators and computers to represent mathematical ideas and construct different representations of mathematical concepts.

(b) Use calculators and computers to develop and use alternate strategies for solving problems.

(c) Use networking and information technologies to solve problems and broaden the scope of inquiry.

(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

(a) Engender a broad array of mathematical modes of thinking through the use of powerful computing tools (including function graphers, curve fitters, symbolic manipulators, dynamic geometric software, and programming languages).

(b) Use calculators, spreadsheets, and statistical packages to solve problems.

(c) Use technology to explore probabilities through simulations.

(d) Use graphing calculators and computer algebra systems in the study and application of the calculus.

O. Teachers will develop perspectives on mathematics as a human endeavor.

(1) Teachers for grades K-8 will be able to:

(a) Understand the dynamic nature of mathematics and its increasingly significant role in social, cultural, and economic development.

(b) Develop an appreciation for the contributions made by various cultures to the growth and development of mathematical ideas.

(c) Investigate the contributions made by individuals, both female and male, and from a variety of cultures, in the development of ancient, modern, and current mathematical topics.

(d) Gain an understanding of the historical development of major school mathematics concepts.

(2) Teachers for grades 5-9 will be able to meet the Standards set for K-8 teachers.

(3) Teachers for grades 7-12 will be able to:

(a) Explore the dynamic nature of mathematics and its increasingly significant role in social, cultural, and economic development.

(b) Gain an understanding of the historical development of major school mathematics concepts.

(c) Understand the historical development of non-Euclidean geometries and the questions relating to the parallel postulate involved in this development.

(d) Develop an appreciation of the contributions made by the various cultures to the growth and development of mathematical ideas.
(e) Investigate the contributions made by individuals, both female and male, and from a variety of cultures, in the development of ancient, modern, and current mathematical topics.