Academic Program

Plan for Assessment of Student Learning Outcomes

Department of Mathematics and Statistics
College of Arts and Sciences
The University of New Mexico

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Academic Programs of Study[1] covered in this document:

- B.S. Mathematics, Applied Mathematics Concentration
- B.S. Mathematics, Mathematics Education Concentration
- B.S. Mathematics, Mathematics of Computation Concentration
- B.S. Mathematics, Pure Mathematics Concentration
- B.S. Statistics

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[1] Academic Program of Study is defined as an approved course of study leading to a certificate or degree reflected on a UNM transcript. A graduate-level program of study typically includes a capstone experience (e.g. thesis, dissertation, professional paper or project, comprehensive exam, etc.).

Contents

A Preface

This document is a revision of the undergraduate Plan for Assessment for the Department of Mathematics and Statistics submitted in Fall 2016.

As of Fall 2018, the Department has 178 undergraduate majors spread across five programs/concentrations: Applied Mathematics (84), Computational Mathematics (15), Mathematics of Education (9), Pure Mathematics (30), Statistics (35), premath or unknown concentration (5), with a total of 27.5 tenure stream faculty in charge of our undergraduate and graduate program. Note that our Department teaches of average, over the 10 years 2007-2016, 46,000 credit hours per year, out of which approximately 6,000 are at the 300-499 level. Since our majors can be expected to take on average, 3-4 courses per year, this implies that more than 2/3 of the students in our classes are not mathematics or statistics majors. In some of our courses the percentage of majors is high, in others we have a large number of engineering and science students from other departments. This document presents a plan to assess our undergraduate program, by assessing only our majors in a set of relevant courses, as outlined herein.

The Undergraduate Program Assessment consists of a list of Student Learning Outcomes (SLOs) for each program/concentration which are assessed both directly and indirectly. **Direct assessment** consists of evaluating the extent to which our students have mastered given program goals. This evaluation is based on student performance on goal-specific tasks in a list of relevant courses, using the rubrics per goal and per course appended to this document. Preparation for future graduate work or mathematical/statistical profession is determined in capstone courses, one per concentration. **Indirect assessment** is based on (1) self-assessment data by students on how well they have mastered a given goal, (2) student feedback on our program, (3) data on student plans after graduation. This data is collected from the exit survey and future student plans.

The original plan submitted Fall 2016 listed between 5-8 SLOs per program/concentration, for a total of 35 SLOs, with significant overlap between them. In addition, the highly similar SLOs were evaluated within the same list of courses, which are taken by students of all programs/concentrations. Since the annual report consists of documenting performance for each SLO, it was deemed to be more meaningful to collect more data for a smaller comprehensive list of SLOs that incorporates the original set but eliminates overlap between different items. This document is the result of a revision aimed at streamlining assessment for ease and transparency of reporting.

The revision consists of devising a comprehensive set of 13 program goals containing, as subsets, the program goals for each of the five programs/concentrations that will be assessed. Data will be collected for each of these goals in a total of 13 courses, for students of all programs/concentrations. There are a total of 47 rubrics that measure the 13 program

goals across the 13 courses. The yearly report will summarize the data obtained from the 47 rubrics. However, differences in the results across programs/concentrations will only be reported if they are found to be meaningful.

The result of this revision is presented in a streamlined manner by first listing the comprehensive list of 13 program goals and summarizing which SLO is relevant for which program/concentration. We then list the courses used to assess each SLO and a 3-year plan for the assessment. The plan is followed by detailed aspects for each program/concentration and, in the appendix, the rubrics for each of the courses, and the exit surveys for each program/concentration. The rubrics are specific to each SLO and each course. Drafts for each of the rubrics are listed in the appendix. These drafts are written by the undergraduate committee but will be improved and adapted each semester by the faculty teaching the courses.

B Assessment Plan: Overview

B.1 Comprehensive list of Broad Program Goals & Measurable Student Learning Outcomes (SLOs)

As described in the preface, the Department's Undergraduate Program is assessed based on students proficiency in a list of measurable Student Learning Outcomes. This list varies among programs/concentrations. However, there is naturally much overlap between concentrations. Thus we begin by listing a comprehensive set of SLOs, and then specifying which subset is used to assess each of the programs/concentrations. The learning outcomes are grouped in three different categories of broad program goals, which are common to all programs/concentrations.

A. Mathematics/Statistics knowledge. Demonstrate understanding of the foundations of mathematics/statistics.

A.1 *Calculus* (MATH 316, 401, 402, STAT 345). Demonstrate understanding of basic definitions and fundamental theorems of calculus. Apply to determine the behaviour of functions, and to compute definite and indefinite integrals. Use definitions to find limits, derivatives and integrals.

A.2 *Linear Algebra* (MATH 314, 316, 321, 375). Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

A.3 *Symbolic and abstract thinking* (MATH 306, 322, 401, 402, STAT 445). Be able to give precise statements and construct logical arguments. Include statements of definitions and theorems, differentiating between hypotheses and conclusions. Understand generalizations of basic concepts.

B. Skills. Demonstrate how to formulate, analyze, and solve problems in mathematics/statistics.

B.1 *Proof writing* (MATH 306, 314, 321, 322, 401, 402). Be able to write clear proofs and form logical conclusions. Include proofs by contradiction, by induction, and disproving by giving counterexamples. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives.

B.2 *Numerical analysis* (MATH 375). Use techniques from calculus to design analytical and numerical methods to solve applied problems, and understand the accuracy and limitations of the methods.

B.3 *Modelling* (MATH 316, 338). Understand and develop an appreciation for how mathematics can be applied to real-world phenomena. Understand simple differential equation models and their applicability.

B.4 *Scientific Computation* (MATH 375, 471). Use computing tools for scientific computation. Implement numerical techniques to solve mathematical problems. Be able to use shared and distributed memory parallel computing platforms.

B.5 *Statistical data analysis* (STAT 428). Demonstrate competence in data summarizing and plotting using a high-level statistical programming language (such as R, SAS, or Stata). Ability to implement statistical software analyses packages for designed experiments, sample surveys and observational studies. Be able to correctly interpret the results, understand the limitations of the procedures, and understand the appropriate scope of conclusions.

B.6 *Probability and statistical modelling* (STAT 345, 445). Be able to solve probability problems, with discrete and continuous univariate random variables and apply the Central Limit Theorem. Be able to understand and apply point estimation, confidence interval and hypothesis testing for a single sample. Demonstrate an understanding of statistical models for standard designed experiments, sample surveys, and observational studies.

B.7 *Geometry* (MATH 306). Be able to show that figures are congruent or similar using transformations. Work fluently with and without coordinates, demonstrating an understanding of the algebra of the Cartesian plane when there are coordinates.

B.8 *Algebra* (MATH 322). Be able to identify various algebraic structures including groups, rings and fields and use algebraic properties and functions which preserve algebraic properties to write concise algebraic proofs.

C. Employability/Technical skills. Translate the undergraduate degree into a viable career path or graduate degree. Demonstrate oral and written communication skills.

C.1 *Communications skills* (MATH 306, 314, 316, 321, 322, 338, 375, 401, 402, 471, STAT 345, 428, 445). Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

C.2 *Preparation* (Capstone courses, data on student employment after graduation). Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

UNM Goals	Knowledge	Skills	Responsibility
A.1	X	X	
A.2	X	X	
A.3	X	X	
B.1	X	X	
B.2	X	X	
B.3	X	X	
B.4	X	X	
B.5	X	X	
B.6	X	X	
B.7	X	X	
B.8	X	X	
C.1	X	X	
C.2	X	X	

B.2 List of SLOs for each program/concentration

Here we list the subset of the comprehensive list of SLOs that is most relevant to each of the Department's five programs/concentrations. The students in the given program/concentration will attain mastery in the listed SLOs upon graduation.

Applied Mathematics:	A1,A2,A3,	B1,B2,B3,B4,	C1,C2
Computational Mathematics:	A1,A2,	B1,B2,B4,	C1,C2
Mathematics of Education:	A1,A2,A3,	B1,B3,B6,B7,B8,	C1,C2
Pure Mathematics:	A1,A2,A3,	B1,B8,	C1,C2
Statistics:	A1,A2,A3,	B5,B6,	C1,C2

B.3 Courses used to assess each program/concentration

For each program/concentration, the Undergraduate Committee has chosen a set of critical mandatory courses that are used to assess the relevant SLOs for that particular program/concentration, listed above in Section B.2. The courses, listed below, are chosen to include:

- mandatory courses critical to most of our majors (such as 401, 314/321),
- mandatory courses particular to a given program/concentration (such as 316 for Applied, 322 for Pure, 471 for Computational, 306 for Math Ed),
- capstone courses for each program (such as 375 for Applied, 402 for Pure, 471 for Computational, 338 for Math Ed).

In addition, all mandatory courses of one concentration already assessed by another concentration are also included in the list. That is: in any given course used for assessment,

all math/stats students will be assessed (with exception of SLO C2, as explained below). These guidelines result in the following list of approximately four courses per concentration, with capstone courses indicated by an asterisk.

Applied Mathematics:	MATH 316,321,375*,401
Computational Mathematics:	MATH 321,375,316 or 322,471*
Mathematics of Education:	MATH 306,314/321,322,338*,401, STAT 345
Pure Mathematics:	MATH 401,402*,321,322
Statistics:	MATH 314/321, STAT 345,428*,445

This list of courses also ensures that all relevant SLOs for any given concentration are addressed. Note that Mathematics of Education has the largest number of courses associated with it, which simply reflects that their mandatory courses includes a large breadth of courses also critical to other concentrations.

In addition, all SLOs will be assessed indirectly using an exit survey. Student preparation (SLO C2) will also be evaluated using data on student employment/graduate study after completing our program. This data will be made available on our course website (see below in Section E).

B.4 Capstone courses

Capstone courses will be used to evaluate the preparation of majors in these courses for graduate study, teaching, or a mathematical/statistical profession (SLO C2). In these courses the instructor will evaluate only those majors in the corresponding concentration by either having them give short presentations, or meeting with them individually to discuss a project or work.

Applied Mathematics:	MATH 375*
Computational Mathematics:	MATH 471*
Mathematics of Education:	MATH 338*
Pure Mathematics:	MATH 402*
Statistics:	STAT 428*

B.5 SLOs addressed by each course

The SLOs addressed by a given course are already indicated by those courses listed in brackets behind each SLO in Section B.1. They are listed below in summarizing form.

Note that most courses support several of the comprehensive list of SLOs, and most SLOs are assessed in several courses. This enables us to assess whether the student has retained and incorporated material from earlier study in their later studies. Hereby it is important to realize that the assessment of a given SLOs depends on the course. For example, the Linear Algebra component A2 in Math 316 is assessed at a different level than the Linear Algebra component in Math 321 or Math 375. Furthermore, the assessment of a student is not equivalent to student performance in the course, which generally includes other learning outcomes.

MATH 306: A3,B1,B7,C1
MATH 314: A2,B1,C1
MATH 316: A1,A2,B3,C1
MATH 321: A2,B1,C1
MATH 322: A3,B1,B8,C1
MATH 338*: B3,C1,C2
MATH 375*: A2,B2,B4,C1,C2
MATH 401: A1,A3,B1,C1
MATH 402*: A1,A3,B1,C1,C2
MATH 471*: B4,C1,C2
STAT 345: A1,B6,C1
STAT 428*: B5,C1,C2
STAT 445: A3,B6,C1

This list results in 47 rubrics, one per SLO per course. These rubrics are drafted by the Undergraduate Committee and improved/ammended as necessary each semester by the faculty teaching the course. The current versions are appended at the end of this document.

C Assessment of Student Learning Three-Year Plan

All programs are expected to measure some outcomes and report annually and to measure all program outcomes at least once over a three-year review cycle.

C.1 Timeline for Assessment

In the table below, briefly describe the timeframe over which your unit will conduct the assessment of learning outcomes selected for the three-year plan. List when outcomes will be assessed and which semester/year the results will be discussed and used to improve student learning (e.g., discussed with program faculty, interdepartmental faculty, advisory boards, students, etc.)

Semester	Assessment Activities	SLOs Assessed
Year 1, Fall Spring	Accumulate data in MATH 314, 316, 401, 471, STAT 345. Accumulate data in MATH 314, 316, 306, 338, 402, STAT 345, 428.	A1-3,C1, B1,3-7.
Year 2, Fall Spring	Accumulate data in MATH 314, 316, 321, 375, STAT 345. Accumulate data in MATH 314, 316, 306, 338, 401, STAT 345, 445.	A1-3,C1, B1-4,6-7
Year 3, Fall Spring	Accumulate data in MATH 314, 316, 322, STAT 345. Accumulate data in MATH 314, 316, 306, 321, 338, 375, STAT 345.	A1-3, C1, B1-4,6-8

This 3-year cycle is chosen so that all courses and all SLOs are assessed at least once in the cycle, with each course being assessed every 3rd time it is offered. That is, courses that are

offered every semester are assessed twice in the cycle, and courses that are offered once per year are assessed once in the cycle.

In addition, courses relevant for our majors that are often taught by non-tenure stream faculty will be assessed every time they are taught. This applies to MATH 306, 314, 316, 338 and STAT 345, most of which are offered as multiple sections courses and all of which are often not covered by the department's tenure-stream faculty.

Note: In all courses, only math/stats majors will be queried. In multi-section courses all majors in all sections will be queried.

Exit surveys will be administered each semester to the graduating class for indirect assessment and data for SLO C2. The graduating students will receive an email with a link to the online exit form, which they answer anonymously. The form depends on the concentration, as it queries students self-assessment in concentration-specific outcomes, in addition to general assessment of our department applicable to all concentrations. A sample form is given at the end of this document. The students will also meet with their faculty advisor in person to give personal feedback, as well as information on their future plans. The faculty advisor will foward the collected information to the Undergraduate Chair who will include it in the annual report.

C.2 How will learning outcomes be assessed?

1. What:

   (a) *For each SLO, briefly describe the means of assessment, i.e., what samples of evidence of learning will be gathered or measures used to assess students' accomplishment of the learning outcomes in the three- year plan?*

C.2.1 BS Mathematics, Applied Mathematics Concentration

Learning outcomes A1,A2,A3 and B1,B2,B3,B4 will be assessed directly by instructors of critical required courses in the major: MATH 316, 321, 375, and 401. These courses give an introduction to several of the foundational areas in modern applied mathematics: linear algebra, calculus, differential equations, and numerical analysis.

Instructors will pose questions on exams that target each of the learning outcomes, based on course-specific rubrics for each SLO. They will then record the data and prepare a report at the end of the semester to be submitted to the undergraduate committee. The students in these classes come from a spectrum of majors in mathematics, statistics, and the sciences. The reports will assess the performance of our majors, distinguishing between different concentrations. A summary of these reports will be given in the annual report. Here, however, differences in performance across concentrations will be reported on only if (1)

a representative number of students is present for each concentration (≥ 4) and (2) the differences are deemed to be sufficiently significant.

Learning outcome C1 will be assessed indirectly in all the four courses. Each course has written homework and exams, and instructors will evaluate the writing and communication skills of each student based on their written work. The evaluation will be based on the clarity, conciseness and correctness of the student's written work.

Learning outcome C2 will be assessed indirectly in Math 375, based on the presentation, maturity and insight shown in complex homework / project assignments that are regularly part of the course. The instructor-prepared reports for this course will include an estimated evaluation of each student's preparation for graduate school or as a contributing member in a mathematical/statistical profession, based on effective written communication.

Learning outcomes A1-3, B1-4, and C2 will be assessed indirectly by surveying students in an exit survey given to the graduating class. For the survey, questions will ask students to self assess their achievement in SLOs A1-3 and B1-4. The survey given to the graduating class will additionally target their experience within the program and future plans after graduation. Data will be collected on the future plans of graduates as part of the annual report, as indirect assessment of C2.

C.2.2 BS Mathematics, Mathematics Education Concentration

Learning outcomes A1,A2,A3 and B1,B6,B7,B8 will be assessed directly by instructors of critical mandatory courses in the major: MATH 306, 314/321, 322, 401, and STAT 345. The math courses give a rigorous, proof-based introduction to several of the foundational areas in modern mathematics: algebra, calculus, discrete structures and geometry. The statistics course gives an introduction to probability and statistics inference for science and engineering students. Instructors will pose questions on exams that target each of the learning outcomes, based on course-specific rubrics for each SLO. They will then record the data and prepare a report at the end of the semester to be submitted to the undergraduate committee. The students in these classes come from a spectrum of majors in mathematics, statistics, and the sciences. The reports will thus present data for all majors and for students within each concentration/program.

Learning outcomes C1-2 will be assessed indirectly in MATH 338. This course is a rigorous course in axiomatic and transformational geometry and is required of all mathematics education majors. The reports in MATH 306 will contain an

additional component that evaluates each students preparation for teaching at the high school level, based and effective written communication. Learning outcome C1 will also be assessed indirectly in all other classes, based on students' written work.

Learning outcomes A1-3, B1,6-8, and C1-2 will be assessed indirectly by surveying students in an exit survey given to the graduating class. Questions will ask students to self assess their achievement in these SLOs. The survey given to the graduating class will additionally target their experience within the program and future plans after graduation. Data will be collected on the future plans of graduates as part of the annual report.

C.2.3 BS Mathematics, Mathematics of Computation Concentration

Learning outcomes A1-3 and B1-2,4 will be assessed directly by instructors of critical mandatory courses in the major: MATH 314/321, 375, 401 and 471. These courses give an introduction to several of the foundational areas in modern computational mathematics: algebra, calculus, differential equations, numerical analysis and parallel computing. Instructors will pose questions on exams and homework that target each of the learning outcomes, based on course-specific rubrics for each SLO. They will then record the data and prepare a report at the end of the semester to be submitted to the undergraduate committee. The students in these classes come from a spectrum of majors in mathematics, statistics, and the sciences. The reports will assess the performance of all majors and of the students within each program/concentration.

Learning outcomes C1-2 will be assessed indirectly in Math 375. This course is required of all mathematics of computation majors. This course has complex homework / project assignments that will be used to assess outcomes C. 1-2. The instructor prepared reports in MATH 375 will contain an additional component that gives the percentage of students who are prepared for graduate school and can demonstrate effective written communication.

Learning outcomes A1-3, B1-2,4, and C1-2 will be assessed indirectly by surveying students in an exit survey given to the graduating class. Questions will ask students to self-assess their achievement in these SLOs. The survey given to the graduating class will additionally target their experience within the program and future plans after graduation. Data will be collected on the future plans of graduates as part of the annual report. Learning outcome C1 will also be assessed indirectly in all other classes, based on students' written work.

C.2.4 BS Mathematics, Pure Mathematics Concentration

Learning outcomes A1-3 and B1,8 will be assessed directly by instructors of critical mandatory courses in the major: MATH 321, 322, 401, and 402. These courses give a rigorous, proof-based introduction to several of the foundational areas in modern mathematics: linear algebra, modern algebra, calculus and logic. Instructors will pose questions on exams that target each of the learning outcomes, based on course-specific rubrics for each SLO. They will then record the data and prepare a report at the end of the semester to be submitted to the undergraduate committee. The students in these classes come from a spectrum of majors in mathematics, statistics, and the sciences. The reports will thus present the performance of all majors and of the students within each concentration/program.

Learning outcomes C1-2 will be assessed indirectly in Math 402. This course is the second semester of the advanced calculus sequence and required of all pure math majors. The reports in Math 402 will contain an additional component that gives the percentage of students who are prepared for graduate school and can demonstrate effective written communication. Learning outcome C1 will also be assessed indirectly in all other classes, based on students' written work.

Learning outcomes A1-3, B1,8, and C1-2 will be assessed indirectly by surveying students in an exit survey given to the graduating class. Questions will ask students to self assess their achievement in these SLOs. The survey given to the graduating class will additionally target their experience within the program and future plans after graduation. Data will be collected on the future plans of graduates as part of the annual report.

C.2.5 BS Statistics

Learning outcomes A1-3, B5-6 and C1 will be assessed directly by instructors of critical courses in the major: STAT 345, 428, 445 and MATH 314/321. These courses give both theoretical and applied treatments of ANOVA and Regression. Instructors will pose questions on assignments (in-class, homework, or exams) that target each of the learning outcomes, based on course-specific rubrics for each SLO. They will then record the data and prepare a report at the end of the semester to be submitted to the undergraduate committee. The students in these classes come from a spectrum of majors in statistics, the sciences, public policy, and social sciences. The reports will thus present the performance of all majors and of the students within each concentration/program.

Learning outcomes C2 will be assessed directly in STAT 445?. This course is required of stat majors.

All learning outcomes will be assessed indirectly in an exit survey given to the graduating class. Questions will ask students to self assess their achievement in these SLOs. The survey given to the graduating class will additionally target their experience within the program and future plans after graduation. Data will be collected on the future plans of graduates as part of the annual report. Learning outcome C1 will also be assessed indirectly in all other classes, based on students' written work.

(b) *Indicate whether each measure is* ***direct*** *or* ***indirect****. If you are unsure, contact* `assessmentas@unm.edu` *for clarification. You should have* ***both direct and indirect measures*** *and at* ***least half of the assessment methods/measures program wide will be direct*** *measures of student learning.*

The instructor reports are direct measures of assessment, except for the portions of each course focusing on communication and preparedness for graduate school/professional life. The exit surveys are indirect.

(c) *Briefly describe the* ***criteria for success*** *related to each direct or indirect measures of assessment. What is the program's performance target (e.g., is an acceptable or better performance by 60% of students on a given measure acceptable to the program faculty)? If scoring rubrics are used to define qualitative criteria and measure performance, include them as appendices.*

Instructors will determine the level of success on graded problems by following a rubric. Since grading scales vary amongst instructors, success will not be quantified simply by reporting raw scores.

If less than 60% of the students are performing at a satisfactory level (or better), the undergraduate committee, in consultation with the faculty, will formulate a plan for improving the course curriculum and procedures in a manner to boost student success.

The undergraduate committee will accumulate the data from exit surveys and report on career paths of the graduates. It is expected that students will be able to successfully apply to graduate school or find employment after graduation.

2. Who: *State explicitly whether the program's assessment will include evidence from all students in the program or a sample. Address the validity of any proposed sample of students. Please note that you are recommended to sample all students in your program; however, sampling approx. 20% of the student population is acceptable if the course's total student population (or student enrollment) exceeds 99 in an academic year. A valid explanation should be provided for samples that are less than 20% of the*

total student population.

The direct assessment measures will present data for all majors in the given semester, in all sections of the courses being queried.

C.3 What is the unit's process to analyze/interpret assessment data and use results to improve student learning?

Briefly describe:

1. *who will participate in the assessment process (the gathering of evidence, the analysis/interpretation, recommendations).*
2. *the process for consideration of the implications of assessment for change:*
    a. *to assessment mechanisms themselves,*
    b. *to curriculum design,*
    c. *to pedagogy*
    ...in the interest of improving student learning.
3. *How, when, and to whom will recommendations be communicated?*

Each semester, class reports will be prepared by those teaching the courses listed in the Table in section C.1. Reports will then be sent to the undergraduate committee who prepare a yearly report which analyzes and interprets this data. At the end of each school year, the undergraduate committee will distribute a survey to the graduating seniors, then summarize the results in the report.

Once a yearly report has been completed, copies will be distributed to the faculty as a whole. A portion of a faculty meeting will then be dedicated to discussing the report, giving faculty an opportunity to recommend avenues for improvement in the assessment mechanisms, curriculum design, and pedagogy.

D Exit Survey

Each major will complete an anonymous online exit survey upon graduation. The online survey contains three parts. The first, "Assessing your skills", is specific to the students concentration/program, the second and third, "Feedback on your learning" and "Future plans", is common for all majors. As a sample, here we include the Exit Survey for an Applied Mathematics major. The wording of the questions in the portion "Assessing your skills" closely follow the wording of the relevant SLOs for the students major listed in section B1.

In addition, the student will meet with their advisor and give any personal feedback as well as feedback on their future plans. The advisor will make notes on these comments and forward them to the undergraduate chair.

The results of the exit survey and the students personal comments will be collected and summarized by the Undergraduate Chair and included in the annual report.

Exit Form 2019 - Applied Mathematics

Please give us your feedback on your studies in the Department of Mathematics and Statistics at UNM. This form has 3 parts. Thank you for your input!

Part 1: Assessing your skills

How well did you achieve each of the following departmental student learning outcomes? Please assess each of the following learning outcomes using this rating scale: 5= Excellent, 2 = Very Good, 3 = Satisfactory, 2 = Questionable, 1 = Unacceptable

A.1 Calculus. Apply calculus to understand the behaviour of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives and integrals.

A.2 Linear Algebra. Effectively perform essential computations in linear algebra, including solving linear systems, least squares problems, computing the eigenvalues of a matrix, and determining linear independence. Apply to diagonalize linear systems of differential equations.

A.3 Symbolic and abstract thinking. Give precise statements of definitions and theorems, differentiating between hypotheses and conclusions. Construct logical arguments. Understand generalizations of basic concepts.

B.1 Proof writing. Be able to construct clear proofs, including proofs by contradiction, by induction, and disproving by giving counterexamples. Be able to state the negation, converse and contrapositive of a mathematical statements.

B.2 Numerical analysis. Use techniques from calculus to design analytical and numerical methods to solve applied problems, and understand the accuracy and limitations of the methods.

B.3 Modelling. Understand simple differential equation models and their applicability to real-world phenomena.

B.4 Scientific Computation. Implement and use numerical techniques to solve mathematical problems, and judge their accuracy.

C.1 Communication. Demonstrate effective written mathematical communication using precise, logically correct and clear statements.

C.2 Preparation. Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

Part 2: Feedback on your learning

What aspects of your education helped you with your learning, and why were they helpful?

1. Please comment on instruction in your courses. Which aspects were helpful, which ones were not?
2. Please comment on homework in your courses. Was it adequate to support your learning?
3. List a highlight of your studies in mathematics and statistics.
4. In hindsight, would you have changed the order in which you took certain courses? if so, why?
5. Did interactions with your peers inside or outside the classroom contribute to your learning?
6. Did you participate in any of the following? Mark all that apply Check all that apply.
    - Independent study course
    - Undergraduate research
    - Undergraduate conference
    - Summer program
    - Internship
7. What might the department change to help you learn more effectively, and what is working well? Please be specific if possible; this is your opportunity to improve the program.

Part 3: Future Plans

Please tell us about your plans.

1. What are your plans after graduation?
    - Employment outside academia
    - Teaching K-12
    - Teaching certificate
    - Graduate School
    - Professional program (such as Medical or Law School)
    - Unknown/Other
2. If known, please add specifics to your answer above (company where you will be employed, school at which you will teach, graduate school you will attend, other plans, etc)

E Rubrics and Reports

Rubrics. This section lists, for each course assessed, the rubrics for all SLOs that are addressed by that course. The purpose of the rubrics is to ensure that assessment occurs independently from the instructor's chosen grading scale. For example, some instructor may consider that a student who gets 80-90% on one of their exam questions deserves a score of "very good" while for another a 90% may be viewed as "excellent", based for example on difficulty of the question.

Course Reports. At the end of each semester the instructors of the courses to be assessed, per the three-year plan outlined above, will send a report summarizing their data to the Undergraduate Chair. The Undergraduate Chair will use the data to write the annual report. The reports for each SLO and each class consists of (1) a description of the tool used for assessment, and (2) a table summarizing the scores, only for the mathematics and statistics majors in the class. Two sample reports are given next. A latex template can be found online at math.unm.edu, under "Undergraduate ⇒ Assessment"

Note that instructors are asked to separately report results for the five different concentrations/programs. To that end, math/stats students should be asked to self-identify which major or concentration they have declared, perhaps with a question on the first exam or on a survey administered to the class.

Annual Reports. The annual reports summarize aggregate data over the previous 3 years for a subset of SLOs, so that in every 3 year window all SLOs have been reported on. The aggregate data summarizes data taken from all courses assessing the particular SLO. To be more specific, we will follow the following timetable:

Year	SLOs reported on
Year 1	A1, B1, B5, C1, C2
Year 2	A2, B3, B6, B7, C1, C2
Year 3	A3, B2, B4, B8, C1, C2

Other Reports. We will summarize on our website vignettes for our undergraduate students that describe what they do after graduating from our department. The goal is to give examples to prospective students of what potential future someone with a BS in Mathematics or Statistics from the University of New Mexico can have.

E.1 Sample Reports

SAMPLE REPORT 1

Course: Math 375 **Section:** **Total number of students:**
SLO: A.2
Assessment: based on (1) question in exam 2 asking students to find and plot the best linear least squares fit to a given data set, and (2) question in final exam asking them to write a given linear system of n given equations for n unknowns in matrix form.

Score	Appl	Comp	Educ	Pure	Stat	Total
5						
4						
3						
2						
1						
Average						

SAMPLE REPORT 2

Course: Math 375 **Section:** **Total number of students:**
SLO: C.2 (Applied math majors only)
Assessment: based on (1) reviewing students matlab code for project 2 (compute and plot spline interpolant to data), and (2) student 10-minute presentation to the class in final review week.

Score	Appl	Comp	Educ	Pure	Stat	Total
5		N/A	N/A	N/A	N/A	
4		N/A	N/A	N/A	N/A	
3		N/A	N/A	N/A	N/A	
2		N/A	N/A	N/A	N/A	
1		N/A	N/A	N/A	N/A	
Average						

E.2 Rubrics Math 306

The following SLOs are assessed in Math 306, a required course for all mathematics majors with concentration in Mathematics Education.

A.3 *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

B.1 *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

B.7 *Geometry.* Be able to show that figures are congruent or similar using transformations. Work fluently with and without coordinates, demonstrating an understanding of the algebra of the Cartesian plane when there are coordinates.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Math 306, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam. Time permitting, short quizzes are sometimes given as well.

A.3 is assessed by proving theorems about geometric figures such as (1) two lines are perpendicular when the slopes are inverse reciprocals of one another, (2) understanding that this slope criterion only applies if the lines are no horizontal/vertical.

B.1 is assessed by asking students to write rigorous proofs of results from high school geometry such as opposite angles in parallelograms are congruent a triangle inscribed in a circe with one side a diameter is a right triangle.

B.7 is assessed by asking students whether or not two polygons in the plane are congruent or similar. It is essential for students to solve problems with and without coordinates.

C.1 is assessed by examining the language and notation students use in class and on written assignments. They label figures and refer to them appropriately. The clearly state hypotheses and results they are using as they prove theorems.

The following rubrics will be used to determine student performance:

Rubric for 306, SLO A.3: *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

A.3 is assessed by proving theorems about geometric figures such as (1) two lines are perpendicular when the slopes are inverse reciprocals of one another, (2) understanding that this slope criterion only applies if the lines are no horizontal/vertical.

Excellent	Reasoning is complete and fully explained. Results which are being used are clearly stated and the argument is well organized. All mathematical terms are used precisely, including symbols and words. Argument shows a solid understanding of mathematical structures.
Very Good	Overall argument is clear but may be missing some minor details. Most results used in the argument are stated. Mathematical language is used well, perhaps with occasional imprecision. Student may lack broad understanding of how a problem or result fits into the bigger picture.
Satisfactory	Fundamental steps in argument are present but may lack clarity. Student rarely states axioms, definitions, and prior results. Precision in language and symbols may frequently be lacking. Student probably does not use larger structures or connections between ideas and results.
Questionable	Argument is flawed, either logically or in the way it is presented or both. Student does not state hypotheses or conclusions clearly and conclusions are sometimes incorrect. Argument shows little understanding of how the result in question fits into a bigger structure.
Unacceptable	Argument is incomplete or incorrect. Student does not explain reasoning adequately and language may be sloppy or incorrect. Work does not show an understanding of the material or of how to write a convincing, cogent argument.

Rubric for 306, SLO B.1: *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

B.1 is assessed by asking students to write rigorous proofs of results from high school geometry such as opposite angles in parallelograms are congruent a triangle inscribed in a circe with one side a diameter is a right triangle.

Excellent	Reasoning is complete and fully explained. Results which are being used are clearly stated and the argument is well organized. All mathematical terms are used precisely, including symbols and words. Argument shows a solid understanding of mathematical structures.
Very Good	Overall argument is clear but may be missing some minor details. Most results used in the argument are stated. Mathematical language is used well, perhaps with occasional imprecision. Student may lack broad understanding of how a problem or result fits into the bigger picture.
Satisfactory	Fundamental steps in argument are present but may lack clarity. Student rarely states axioms, definitions, and prior results. Precision in language and symbols may frequently be lacking. Student probably does not use larger structures or connections between ideas and results.
Questionable	Argument is flawed, either logically or in the way it is presented or both. Student does not state hypotheses or conclusions clearly and conclusions are sometimes incorrect. Argument shows little understanding of how the result in question fits into a bigger structure.
Unacceptable	Argument is incomplete or incorrect. Student does not explain reasoning adequately and language may be sloppy or incorrect. Work does not show an understanding of the material or of how to write a convincing, cogent argument.

Rubric for 306, SLO B.7: *Geometry.* Be able to show that figures are congruent or similar using transformations. Work fluently with and without coordinates, demonstrating an understanding of the algebra of the Cartesian plane when there are coordinates.

B.7 is assessed by asking students whether or not two polygons in the plane are congruent or similar. It is essential for students to solve problems with and without coordinates.

Excellent	Understands how to compute lengths and determine angles in Euclidean and non-Euclidean geometries. Is able to represent geometric transformations algebraically. Is able to interpret algebraic equations geometrically. Is able to use vectors to represent geometric situations. Carefully defines variables when using coordinates. Understands how to use transformations, coordinates, and vectors in the plane to solve problems in $\mathbb{R}^2$ and $\mathbb{R}^3$. Works fluently with transformations applied to shapes in the plane to show congruence and similarity. Comfortably and confidently applies transformations to prove theorems (e.g. base angles in an isosceles triangle are congruent).
Very Good	Can often compute lengths and determine angles in Euclidean and non-Euclidean geometries. Often able to represent geometric transformations algebraically. Is able to interpret algebraic equations geometrically. Usually defines variables when working in coordinates. Works with transformations but does not necessarily understand them well as functions. Can apply a transformation to points and polygons. Understands geometric proofs that use transformations.
Satisfactory	Can often compute lengths and determine angles in Euclidean and non-Euclidean geometries. Struggles to view transformations as functions. Understands the meaning of variables when working with coordinates. Can understand some calculations and arguments with transformations but is unable to consistently make these calculations or produce successful arguments using transformations.
Questionable	Can follow reasoning with coordinates and transformations in a coordinate system but has difficulty computing lengths and determine angles in Euclidean and non-Euclidean geometries. Careless in use of variables when working in a coordinate system. Can successfully apply some transformations (especially translations) to points. Struggles to use transformations as a tool in proofs and lacks understanding of a transformation as a mathematical object, i.e. a function.
Unacceptable	Has difficulty using coordinates to solve problems, with or without transformations. Does not understand the link between transformations and functions. Is sloppy with use of variables representing coordinates. Can not successfully apply transformations to points or shapes. Does not understand how to use transformations to show congruence or similarity of shapes.

Rubric for 306, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

C.1 is assessed by examining the language and notation students use in class and on written assignments. They label figures and refer to them appropriately. The clearly state hypotheses and results they are using as they prove theorems.

Excellent	Uses mathematical language precisely. Constructs clear arguments which communicate a line of reasoning to others. States all hypotheses clearly and records measurements and calculations with an appropriate level of precision. Can interpret written reasoning of other students even if they are unable to formulate their thought precisely.
Very Good	Uses mathematical language well. Constructs good arguments with an occasional missing step or flaw. States many hypotheses and often records measurements and calculations with an appropriate level of precision. Can sometimes interpret written reasoning of other students.
Satisfactory	Sometimes uses mathematical language well. Can not always distinguish a good argument from a bad argument and presents both good and bad arguments. Frequently omits important hypotheses and records measurements and calculations with an inappropriate level of precision.
Questionable	Is often faulty and imprecise in use of mathematical language. Frequently presents bad or flawed reasoning. Does not understand the importance of stating hypotheses or recording measurements with appropriate precision.
Unacceptable	Unable to use appropriate mathematical language in arguments. Unable to construct or identify cogent arguments.

E.3 Rubrics Math 314

The following SLOs are assessed in Math 314. Either Math 314 or Math 321 is a required course for all mathematics majors with concentration in Mathematics Education or Computational Mathematics, and for all Statistics majors.

A.2 *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

B.1 *Proof writing* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Math 314, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam. Time permitting, short quizzes are sometimes given as well.

A.2 can be assessed by asking students to (i) calculate by hand a basis for each of several of the fundamental subspaces of a matrix of about three or four rows and columns, or (ii) calculate an explicit solution to a least-squares minimization problem, or (iii) calculate by hand the diagonalization of a small square matrix and apply that to a system of differential equations.

B.1 can be assessed by asking students to (i) use a counter-example to prove that a given subset of vectors is not a subspace or that a map is not linear, and (ii) prove that a given subset is a subspace or that a map is linear or validate that an algebraic relation follows from some assumptions using only axioms.

C.1 is assessed based on the clarity of the presentation of the students work in exams.

The following rubrics will be used to determine student performance:

Rubric for 314, SLO A.2: *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

A.2 can be assessed by asking students to (i) calculate by hand a basis for each of several of the fundamental subspaces of a matrix of about three or four rows and columns, or (ii) calculate an explicit solution to a least-squares minimization problem, or (iii) calculate by hand the diagonalization of a small square matrix and apply that to a system of differential equations.

Excellent	Clear and well organized work, calculations and results are correct, demonstrating full understanding of all steps taken.
Very Good	Good presentation and calculations and results are correct, demonstrating full understanding of all steps taken.
Satisfactory	Good presentation with most steps shown and minor algebra mistakes, but otherwise consistent work.
Questionable	Unclear presentation, mistakes in basic calculations, incorrect results, outline of the argument is correct.
Unacceptable	Sloppy, unclear presentation, incorrect results, inconsistencies in the work.

Rubric for 314, SLO B.1: *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

B.1 can be assessed by asking students to (i) use a counter-example to prove that a given subset of vectors is not a subspace or that a map is not linear, and (ii) prove that a given subset is a subspace or that a map is linear or validate that an algebraic relation follows from some assumptions using only axioms.

Excellent	Accurate and complete argument with proper notation, with proper sentences and clear logic.
Very Good	Accurate argument with proper notation.
Satisfactory	Mostly correct logic, with some errors or hard-to-follow writing.
Questionable	Incomplete logic or serious errors in calculations.
Unacceptable	Argues from special cases or has incorrect logic.

Rubric for 314, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements. Communicate well, orally and in writing, in an applied mathematics context.

C.1 is assessed based on the clarity of the presentation of the students work in exams.

Excellent	Exemplary writeup where the mathematical and English language is highly articulate.
Very Good	Cogent writeup where the mathematical and English language is easily understandable.
Satisfactory	Comprehensible writeup where the mathematical and English language is decipherable.
Questionable	Incomplete writeup where the mathematical and English language is incomplete.
Unacceptable	Poor writeup where the mathematical and English language is unclear.

E.4 Rubrics Math 316

The following SLOs are assessed in Math 316, a required course for all mathematics students with concentration in Applied Mathematics:

A.1 *Calculus.* Demonstrate understanding of foundations, including knowledge of basic definitions and fundamental theorems. Apply calculus to understand the behaviour of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives and integrals.

A.2 *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

B.3 *Modelling.* Understand and develop an appreciation for how mathematics can be applied to real-world phenomena. Understand simple differential equations models and their applicability.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Math 316, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam. Time permitting, short quizzes are sometimes given as well.

A.1 is assessed by asking students to find exact solutions to differential equations that require finding definite integrals, or finding solutions formulated as integrals. Examples arise when aplying the method of separation of variables, the method of integrating factors, reduction of order and variation of parameters.

A.2 is assessed by asking students to write 2x2 systems of first order differential equations in matrix form, find the eigenvalues and eigenvectors of the matrix, write the solution to the system as a linear combination of fundamental solutions, and graph the resulting family of solutions in the plane.

B.3 is assessed by asking students to find models for simple applications or to interpret all components present in a model. Applications students explore include linear systems such as springs and mechanical vibrations, mixing problems, single population models with or without a "harvest" component, and nonlinear systems such as interaction between populations of two species or the nonlinear pendulum.

C.1 is assessed based on the clarity of the presentation of the students work in exams.

The following rubrics will be used to determine student performance:

Rubric for 316, SLO A.1 *Calculus.* Demonstrate understanding of foundations, including knowledge of basic definitions and fundamental theorems. Apply calculus to understand the behaviour of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives and integrals.

SLO A.1 is assessed by asking students to find exact solutions to differential equations that require finding definite integrals, or finding solutions formulated as integrals. Examples arise when aplying the method of separation of variables, the method of integrating factors, reduction of order and variation of parameters.

Excellent	Exemplary solutions to all integrals, including correct algebra, clearly shown well-organized work, correct form of solutions that can only be given in integral representation, correct description of basic properties of these solutions, such as unbounded behaviour near asymptotes, roots, local extrema. The solution is highly well organized, with all steps shown in appropriate detail and clearly justified.
Very Good	Cogent solutions to all integrals, including correct algebra, clearly shown well-organized work, correct form of solutions that can only be given in integral representation, correct description of basic properties of these solutions, such as unbounded behaviour near asymptotes, roots, local extrema. The solution is well organized, with all steps shown and easily understandable.
Satisfactory	Understandable solution with minor algebra mistakes, or small errors and inconsistencies in properties of resulting functions. The solution is reasonably well organized with most steps shown.
Questionable	Major algebra mistakes, major inconsistent results, but student realizes inconsistencies, unclear writup. The method of solution is mostly correct but the presentation is not well organized and many important steps are not shown.
Unacceptable	Inconsistent result, blatantly incorrect algebra, sloppy unclear writeup. The work shown is unclear.

Rubric for 316, SLO A.2 *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

SLO A.2 is assessed by asking students to write 2x2 systems of first order differential equations in matrix form, find the eigenvalues and eigenvectors of the matrix, write the solution to the system as a linear combination of fundamental solutions, and graph the resulting family of solutions in the plane.

Excellent	Correct solution to a 2x2 linear system of equations, clearly showing all steps in a legible, neat, well-organized presentation, demonstrating full understanding of all steps taken. Graphical representation of solution curves is well labelled, clearly indicating type of equilibrium, showing several solution curves and the direction of increasing time. Mathematical language and clarity of the presentation is highly articulate.
Very Good	Correct solution to a 2x2 linear system of equations, showing all steps in a cogent presentation, demonstrating full understanding of all steps taken. Graphical representation of solution curves is correct and complete. Mathematical language and clarity of presentation is easily understandable.
Satisfactory	Good presentation with most steps shown and minor algebra mistakes, but otherwise consistent work. Mathematical language and clarity of presentation is decipherable.
Questionable	Unclear presentation, algebra mistakes, incorrect results, outline of the argument is correct. Mathematical language and clarity of presentation is incomplete.
Unacceptable	Sloppy, unclear presentation, incorrect results, inconsistencies in the work. Mathematical language and clarity of presentation is unclear.

Rubric for SLO 316, B.3 *Modelling.* Understand and develop an appreciation for how mathematics can be applied to real-world phenomena. Understand simple differential equations models and their applicability.

SLO B.3 is assessed by asking students to find models for simple applications or to interpret all components present in a model. Applications students explore include linear systems such as springs and mechanical vibrations, mixing problems, single population models with or without a "harvest" component, and nonlinear systems such as interaction between populations of two species or the nonlinear pendulum.

Excellent	Exemplary discussion which demonstrates full comprehension of all terms in the model. Student has a clear understanding of what the differential equations models and can deduce properties of the solution based on values of the parameters in the model. Student explains contribution of each term using highly articulate Mathematical and English language.
Very Good	Cogent discussion which demonstrates good comprehension of the model. Student deduces correct properties of the solution based on values of the parameters in the model. Student explains contribution of each term using easily understandable Mathematical and English language.
Satisfactory	Understandable discussion which demonstrates reasonable comprehension of all terms in the model. Mathematical and English language used to describe the contribution is decipherable.
Questionable	Incomplete discussion which demonstrates a partial comprehension of the model. Student indicates a partial understanding of what the differential equations models, and of the properties of solutions as functions of parameters in the model. Mathematical and English language is incomplete.
Unacceptable	Poorly written discussion which demonstrates little or no comprehension of the model. Student does not demonstrate an understanding of what the differential equations models, and cannot deduce properties of solutions as a function of parameters in the model. Mathematical and English language is unclear.

Rubric for 316, SLO C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements. Communicate well, orally and in writing, in an applied mathematics context.

SLO C.1 is assessed based on the clarity of the presentation of the students work in exams.

Excellent	Exemplary writeup where the mathematical and English language is highly articulate.
Very Good	Cogent writeup where the mathematical and English language is easily understandable.
Satisfactory	Comprehensible writeup where the mathematical and English language is decipherable.
Questionable	Incomplete writeup where the mathematical and English language is incomplete.
Unacceptable	Poor writeup where the mathematical and English language is unclear.

E.5 Rubrics Math 321

Math 321 is required of all mathematics majors with concentration in Applied Mathematics or Pure Mathematics. Math 321 or Math 314 is required of all other mathematics and statistics majors. The following SLOs are assessed in Math 321.

A.2 *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

B.1 *Proof writing* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Math 321, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam. Time permitting, short quizzes are sometimes given as well.

A.2 can be assessed by asking students to (i) calculate by hand a basis for each of several of the fundamental subspaces of a matrix of about three or four rows and columns, or (ii) calculate an explicit solution to a least-squares minimization problem, or (iii) calculate by hand the diagonalization of a small square matrix and apply that to a system of differential equations.

B.1 can be assessed by asking students one of the following: (i) asked to determine if a map is linear and proved proof or counterexample to validate their answer; (ii) ...

C.1 is assessed based on the clarity of the presentation of the students work in exams.

The following rubrics will be used to determine student performance:

Rubric for 321, SLO A.2: *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

A.2 can be assessed by asking students to (i) calculate by hand a basis for each of several of the fundamental subspaces of a matrix of about three or four rows and columns, or (ii) calculate an explicit solution to a least-squares minimization problem, or (iii) calculate by hand the diagonalization of a small square matrix and apply that to a system of differential equations.

Excellent	Clear and well organized work, calculations and results are correct, demonstrating full understanding of all steps taken. Mathematical and English language is highly articulate.
Very Good	Good presentation and calculations and results are correct, demonstrating full understanding of all steps taken.
Satisfactory	Good presentation with most steps shown and minor algebra mistakes, but otherwise consistent work. Mathematical and English language is decipherable.
Questionable	Unclear presentation, mistakes in basic calculations, incorrect results, outline of the argument is correct. Mathematical and English language is incomplete.
Unacceptable	Sloppy, unclear presentation, incorrect results, inconsistencies in the work. Mathematical and English language is unclear.

Rubric for 321, SLO B.1: *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

Excellent	Accurate and complete argument with proper notation, with proper sentences and clear logic.
Very Good	Accurate argument with proper notation.
Satisfactory	Mostly correct logic, with some errors or hard-to-follow writing.
Questionable	Incomplete logic or serious errors in calculations.
Unacceptable	Argues from special cases or has incorrect logic.

Rubric for 321, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements. Communicate well, orally and in writing, in an applied mathematics context.

SLO C.1 is assessed based on the clarity of the presentation of the students work in exams.

Excellent	Exemplary writeup where the mathematical and English language is highly articulate.
Very Good	Cogent writeup where the mathematical and English language is easily understandable.
Satisfactory	Comprehensible writeup where the mathematical and English language is decipherable.
Questionable	Incomplete writeup where the mathematical and English language is incomplete.
Unacceptable	Poor writeup where the mathematical and English language is unclear.

E.6 Rubrics Math 322

The following SLOs are assessed in Math 322, a required course for all mathematics students with concentration in Pure Mathematics.

A.3 *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

B.1 *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

B.8 *Algebra.* Be able to identify various algebraic structures including groups, rings and fields and use algebraic properties and functions which preserve algebraic properties to write concise algebraic proofs.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Math 322, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam.

A.3 can be assessed by questions which involve an "if and only if" statement or by questions which naturally involve a proof by contrapositive or proof by contradiction.

B.1 will be naturally be assessed in most exam questions.

B.8 can be assessed by questions pertaining to groups, rings and fields and their substructures.

C.1 is assessed based on the clarity of the presentation of the students work in exams.

The following rubrics will be used to determine student performance:

Rubric for 322, SLO A.3: *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

A.3 can be assessed by questions which involve an "if and only if" statement or by questions which naturally involve a proof by contrapositive or proof by contradiction.

Excellent	Exemplary proof which demonstrates full comprehension of the fundamentals of logic. The chosen strategy for the proof is natural, well motivated, and effective. Student has a clear understanding of what constitutes the converse or contrapositive statement. Mathematical and English language is highly articulate.
Very Good	Cogent proof which demonstrates good comprehension of the fundamentals of logic. The chosen strategy for the proof is apparent and effective. Student has a good understanding of what constitutes the converse or contrapositive statement. Mathematical and English language is easily understandable.
Satisfactory	Understandable proof which demonstrates reasonable comprehension of the fundamentals of logic. The chosen strategy for the proof is recognizable and mostly effective. Student has an understanding of what constitutes the converse or contrapositive statement. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Incomplete proof which demonstrates a partial comprehension of the fundamentals of logic. The chosen strategy for the proof has potential. Proof shows an indication of some comprehension of the pertinent mathematical definitions. Student indicates a partial understanding of what constitutes the converse or contrapositive statement. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written proof which demonstrates little or no comprehension of the fundamentals of logic. The chosen strategy for the proof is unclear and/or ineffective. Student does not demonstrate an understanding of what constitutes the converse or contrapositive statement. Errors are striking. Mathematical and English language is unclear.

Rubric for 322, SLO B.1: *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

B.1 will be naturally be assessed in most exam questions.

Excellent	Exemplary proof, with full justification for each step and the logic of argument flows naturally. The chosen strategy for the proof is natural, well motivated, and effective. Proof shows full comprehension of the pertinent mathematical definitions. Mathematical and English language is highly articulate.
Very Good	Cogent proof, with most key steps clearly justified. The chosen strategy for the proof is apparent and effective. Proof shows good comprehension of the pertinent mathematical definitions. Mathematical and English language is easily understandable.
Satisfactory	Comprehensible proof, with justification for the essential steps. The chosen strategy for the proof is recognizable and mostly effective. Proof shows reasonable comprehension of the pertinent mathematical definitions. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Partial progress on the proof, only some essential steps are justified. The chosen strategy for the proof has potential. Proof shows an indication of some comprehension of the pertinent mathematical definitions. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written proof, essential steps lack justification. The chosen strategy for the proof is unclear and/or ineffective. Comprehension of the pertinent mathematical definitions is uncertain. Errors are striking. Mathematical and English language is unclear.

Rubric for 322, SLO B.8: *Algebra.* Be able to identify various algebraic structures including groups, rings and fields and use algebraic properties and functions which preserve algebraic properties to write concise algebraic proofs.

B.8 can be assessed by questions pertaining to groups, rings and fields and their substructures.

Excellent	Exemplary proof pertaining to groups, rings, fields, or some substructures of the aforementioned structures. The chosen strategy for the proof is natural, well motivated, and effective. Student has a clear understanding of what properties need to be shown to exhibit the set along with binary operation(s) is the algebraic structure in question. Mathematical and English language is highly articulate.
Very Good	Cogent proof pertaining to groups, rings, fields, or some substructures of the aforementioned structures. The chosen strategy for the proof is apparent and effective. Student has a good understanding of what properties need to be shown to exhibit the set along with binary operation(s) is the algebraic structure in question. Mathematical and English language is easily understandable.
Satisfactory	Understandable proof pertaining to groups, rings, fields, or some substructures of the aforementioned structures. The chosen strategy for the proof is recognizable and mostly effective. Student has an understanding of what properties need to be shown to exhibit the set along with binary operation(s) is the algebraic structure in question. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Incomplete proof which demonstrates a partial comprehension of groups, rings, fields, or some substructures of the aforementioned structures.. The chosen strategy for the proof has potential. Proof shows an indication of some comprehension of the pertinent mathematical definitions. Student indicates a partial understanding of what properties need to be shown to exhibit the set along with binary operation(s) is the algebraic structure in question. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written proof which demonstrates little or no comprehension of showing a set with one (or two binary operations) is a specific type of group, ring field or some substructure of the aforementioned structures. The chosen strategy for the proof is unclear and/or ineffective. Student does not demonstrate an understanding of what needs to be shown to exhibit the set along with binary operation(s) is the algebraic structure in question. Errors are striking. Mathematical and English language is unclear.

Rubric for 322, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

SLO C.1 is assessed based on the clarity of the presentation of the students work in exams.

Excellent	Exemplary writeup where the mathematical and English language is highly articulate.
Very Good	Cogent writeup where the mathematical and English language is easily understandable.
Satisfactory	Comprehensible writeup where the mathematical and English language is decipherable.
Questionable	Incomplete writeup where the mathematical and English language is incomplete.
Unacceptable	Poor writeup where the mathematical and English language is unclear.

E.7 Rubrics Math 338

The following SLOs are assesssed in Math 338, which is a required course for mathematics students with concentration in Mathematics Education.

B.3 *Modelling.* Understand and develop an appreciation for how mathematics can be applied to real-world phenomena. Understand simple differential equations models and their applicability.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

C.2 *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

In Math 338, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, a final exam, in class participation/presentations?? quizzes?

B.3 is assessed by asking students to find models for simple applications or to interpret all components present in a model. Applications students explore include (1) using parabolas for telescopes (to focus light coming from a long distance away) and for creating solar energy (focusing the light from the sun): these applications highlight the focus/directrix definition of a parabola, (2) Archimedes' calculation of the area of the circle/volume of a sphere. The ancient Greek "method of exhaustion" is a precursor to modern calculus.

C.1 is assessed by examining the language and notation students use in class and on written assignments. They label figures and refer to them appropriately. The clearly state hypotheses and results they are using as they prove theorems.

C.2 is assessed by the clarity of oral and written presentations. Students can explain concepts from high school algebra, geometry, and trigonometry using rigorous language and arguments that they have learned in their upper level courses (only students with concentration in Mathematics Education will be evaluated).

The following rubrics will be used to determine student performance:

Rubric for 338, SLO B.3: *Modelling.* Understand and develop an appreciation for how mathematics can be applied to real-world phenomena. Understand simple differential equations models and their applicability.

SLO B.3 is assessed by asking students to find models for simple applications or to interpret all components present in a model. Applications students explore include (1) using parabolas for telescopes (to focus light coming from a long distance away) and for creating solar energy (focusing the light from the sun): these applications highlight the focus/directrix definition of a parabola, (2) Archimedes' calculation of the area of the circle/volume of a sphere. The ancient Greek "method of exhaustion" is a precursor to modern calculus.

Excellent	Exemplary discussion which demonstrates full comprehension of all terms in the model. Student has a clear understanding of what the differential equations models and can deduce properties of the solution based on values of the parameters in the model. Student explains contribution of each term using highly articulate Mathematical and English language.
Very Good	Cogent discussion which demonstrates good comprehension of the model. Student deduces correct properties of the solution based on values of the parameters in the model. Student explains contribution of each term using easily understandable Mathematical and English language.
Satisfactory	Understandable discussion which demonstrates reasonable comprehension of all terms in the model. Mathematical and English language used to describe the contribution is decipherable.
Questionable	Incomplete discussion which demonstrates a partial comprehension of the model. Student indicates a partial understanding of what the differential equations models, and of the properties of solutions as functions of parameters in the model. Mathematical and English language is incomplete.
Unacceptable	Poorly written discussion which demonstrates little or no comprehension of the model. Student does not demonstrate an understanding of what the differential equations models, and cannot deduce properties of solutions as a function of parameters in the model. Mathematical and English language is unclear.

Rubric for 338, SLO C.1: *Communications skills* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

SLO C.1 is assessed by examining the language and notation students use in class and on written assignments. They label figures and refer to them appropriately. The clearly state hypotheses and results they are using as they prove theorems.

Excellent	Uses mathematical language precisely. Constructs clear arguments which communicate a line of reasoning to others. States all hypotheses clearly and records measurements and calculations with an appropriate level of precision. Can interpret written reasoning of other students even if they are unable to formulate their thought precisely.
Very Good	Uses mathematical language well. Constructs good arguments with an occasional missing step or flaw. States many hypotheses and often records measurements and calculations with an appropriate level of precision. Can sometimes interpret written reasoning of other students.
Satisfactory	Sometimes uses mathematical language well. Can not always distinguish a good argument from a bad argument and presents both good and bad arguments. Frequently omits important hypotheses and records measurements and calculations with an inappropriate level of precision.
Questionable	Is often faulty and imprecise in use of mathematical language. Frequently presents bad or flawed reasoning. Does not understand the importance of stating hypotheses or recording measurements with appropriate precision.
Unacceptable	Unable to use appropriate mathematical language in arguments. Unable to construct or identify cogent arguments.

Rubric for 338, SLO C.2: *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

C.2 is assessed by the clarity of oral and written presentations. Students can explain concepts from high school algebra, geometry, and trigonometry using rigorous language and arguments that they have learned in their upper level courses (only students with concentration in Mathematics Education will be evaluated).

Excellent	Understands the mathematical foundations of ...
Very Good	Can reason about ..
Satisfactory	Can identify when ...
Questionable	Can sometimes identify ..
Unacceptable	Does not understand how to show ..

E.8 Rubrics Math 375

The following SLOs are assessed in Math 375, a required course for all mathematics majors with concentration in Applied Mathematics and in Computational Mathematics.

A.2 *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

B.2 *Numerical analysis.* Use techniques from calculus to design analytical and numerical methods to solve applied problems, and understand the accuracy and limitiations of the methods.

B.4 *Scientific Computation.* Use computing tools for scientific computation. Implement numerical techniques to solve mathematical problems. Be able to use shared and distributed memory parallel computing platforms.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

C.2 *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

In Math 375, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam.

A.2 can be assessed by asking students to (i) write the system of n linear equations determining a numerical approximation in matrix form and implementing it in MATLAB, or (ii) solving a 3x3 linear system using Gauss Elimination and finding the LU, PLU or QR factorization of the associated matrix, or (iii) finding least squares solutions for linear systems and estimating the least squares error.

B.2 can be assessed by asking students to derive numerical methods to approximate (i) derivatives or (ii) solutions to nonlinear equations (s.a. fixed-point iteration or Newton's method) or (iii) solutions to first order initial value problems (s.a. Euler's method) and, in all cases, use Taylor series approximations to obtain estimates for the approximation error.

B.4 is assessed by asking students to implement an approximation method and discuss convergence properties and accuracies. Possible methods to choose from include (i) iterative methods to solve first order equations, (ii) methods for numerical integration, (iii) methods to solve differential equations, (iv) methods for interpolation.

C.1 is assessed based on the clarity of the presentation of the students work in exams.

C.2 is assessed using instructors evaluation of students understanding and maturity based on students ability to explain, discuss and present the material clearly, as evidenced in students work and interactions with the faculty (only students with concentration in Computational Mathematics will be evaluated).

The following rubrics will be used to determine student performance

Rubric for 375, SLO A.2: *Linear Algebra.* Demonstrate understanding of foundations, including basic manipulation, the four fundamental vector spaces of a matrix, linear independence, and abstract vector spaces. Be able to solve linear systems, least squares problems, eigenvalue problems, and apply to diagonalize linear systems of differential equations.

SLO A.2 can be assessed by asking students to (i) write the system of n linear equations determining a numerical approximation in matrix form and implementing it in MATLAB, or (ii) solving a 3x3 linear system using Gauss Elimination and finding the LU, PLU or QR factorization of the associated matrix, or (iii) finding least squares solutions for linear systems and estimating the least squares error.

Excellent	Exemplary solutions, clear and well organized work, correct algebra, demonstrating full understanding of all steps taken. Mathematical and English language is highly articulate.
Very Good	Correct solutions, showing all steps in a cogent presentation, demonstrating full understanding of all steps taken. Mathematical and English language is easily understandable.
Satisfactory	Good presentation with most steps shown and minor algebra mistakes, but otherwise consistent work. Mathematical and English language is decipherable.
Questionable	Unclear presentation, algebra mistakes, incorrect results, outline of the argument is correct. Mathematical and English language is incomplete.
Unacceptable	Sloppy, unclear presentation, incorrect results, inconsistencies in the work. Mathematical and English language is unclear.

Rubric for 375, SLO B.2: *Numerical analysis.* Use techniques from calculus to design analytical and numerical methods to solve applied problems, and understand the accuracy and limitiations of the methods.

SLO B.2 is assessed by asking students to derive numerical methods to approximate (i) derivatives or (ii) solutions to nonlinear equations (s.a. fixed-point iteration or Newton's method) or (iii) solutions to first order initial value problems (s.a. Euler's method) and, in all cases, use Taylor series approximations to obtain estimates for the approximation error.

Excellent	Exemplary, complete and clear derivation of the method, including explanation of details and special cases, with full justification of each step. The logic of the arguments flows naturally. Exemplary, complete and clear derivation of expressions for the approximation error using Taylor series. Mathematical and English language is highly articulate.
Very Good	Cogent derivation of the numerical method, with most key steps clearly justified. Cogent derivation of expressions for the approximation error using Taylor series, including most steps. Mathematical and English language is easily understandable.
Satisfactory	Comprehensible derivation of the numerical method, with all major steps shown and minor algebra mistakes, but otherwise consistent work. Correct statement of Taylor series or Taylor polynomial approximation. Mathematical and English language is decipherable.
Questionable	Unclear presentation, however outline of the argument is correct. Mathematical and English language is incomplete.
Unacceptable	Sloppy, unclear presentation, incorrect results, inconsistencies in the work. Mathematical and English language is unclear.

Rubric for 375, SLO B.4: *Scientific Computation.* Use computing tools for scientific computation. Implement numerical techniques to solve mathematical problems. Be able to use shared and distributed memory parallel computing platforms.

SLO B.4 is assessed by asking students to implement an approximation method and discuss convergence properties and accuracies. Possible methods to choose from include (i) iterative methods to solve first order equations, (ii) methods for numerical integration, (iii) methods to solve differential equations, (iv) methods for interpolation.

Excellent	Exemplary use and implementation of the numerical method. Student has a complete understanding of the accuracy of the method. Mathematical and English language is highly articulate.
Very Good	Cogent use and implementation of the numerical method. Student has a good understanding of the accuracy of the method. Mathematical and English language is easily understandable.
Satisfactory	Comprehensible use and implementation of the numerical method. Student gives at least some indication of the accuracy of the method. Mathematical and English language is decipherable.
Questionable	Incomplete use and implementation of the numerical method. Student may show some comprehension of the accuracy of the method. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poor use and implementation of the numerical method. Unclear whether or not the student understands the method. Errors are striking. Mathematical and English language is unclear.

Rubric for 375, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

SLO C.1 is assessed based on the clarity of the presentation of the students work in exams.

Excellent	Exemplary writeup where the mathematical and English language is highly articulate.
Very Good	Cogent writeup where the mathematical and English language is easily understandable.
Satisfactory	Comprehensible writeup where the mathematical and English language is decipherable.
Questionable	Incomplete writeup where the mathematical and English language is incomplete.
Unacceptable	Poor writeup where the mathematical and English language is unclear.

Rubric for 375, SLO C.2: *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

SLO C.2 is assessed using instructors evaluation of students understanding and maturity based on students ability to explain, discuss and present the material clearly, as evidenced in students work and interactions with the faculty (only students with concentration in Computational Mathematics will be evaluated).

Excellent	Student is unquestionably able to explain course material coherently to others, including awareness of subtle aspects and solid understanding of the overall context. Students written work, including computer programs, is clear and easy to follow.
Very Good	Student is able to explain course material coherently to others, with good understanding of context but not fully clear on subtleties of the material. Students written work, including computer programs, is clear and easy to follow.
Satisfactory	Student is able to explain course material coherently to others, showing reasonable understanding of material and context. Students written work, including computer programs, is correct and complete, but not easy to follow.
Questionable	Student is able to summarize course material without good understanding of the material and context. Students written work, including computer programs, is correct, but incomplete and not easy to follow.
Unacceptable	Student is unable to articulate a correct summary of most of the course material. Students written work, including computer programs, is incorrect and not easy to follow.

E.9 Rubrics Math 401

The following SLOs are assessed in Math 401, a required course for all mathematics majors.

A.1 *Calculus.* Demonstrate understanding of foundations, including knowledge of basic definitions and fundamental theorems. Apply calculus to understand the behaviour of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives and integrals.

A.3 *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

B.1 *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Math 401, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam.

A.1 can be assessed by asking students to prove the existence of a limit or convergence of a sequence using the formal ϵ-δ or ϵ-N definition.

A.3 can be assessed by questions which involve an "if and only if" statement or by questions which naturally involve a proof by contrapositive or proof by contradiction.

B.1 will be naturally be assessed in most exam questions.

C.1 is assessed based on the clarity of the presentation of the students work in exams.

The following rubrics will be used to determine student performance:

Rubric for 401, SLO A.1: *Calculus.* Demonstrate understanding of foundations, including knowledge of basic definitions and fundamental theorems. Apply calculus to understand the behaviour of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives and integrals.

A.1 can be assessed by asking students to prove the existence of a limit or convergence of a sequence using the formal ϵ-δ or ϵ-N definition.

Excellent	Exemplary ϵ-δ or ϵ-N proof, with full justification for each step and the logic of argument flows naturally. Choice of the threshold δ or N is well motivated and effective for the given problem. Mathematical and English language is highly articulate.
Very Good	Cogent ϵ-δ or ϵ-N proof, with most key steps clearly justified. Choice of the threshold δ or N is effective for the given problem. Mathematical and English language is easily understandable.
Satisfactory	Comprehensible ϵ-δ or ϵ-N proof, with justification for the essential steps. Choice of the threshold δ or N is effective for the given problem. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Partial progress on the ϵ-δ or ϵ-N proof, only some essential steps are justified. Some visible progress on selecting the choice of the threshold δ or N for the given problem. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written ϵ-δ or ϵ-N proof, essential steps lack justification. Choice of the threshold δ or N is unclear or is ineffective for the given problem. Errors are striking. Mathematical and English language is unclear.

Rubric for 401, SLO A.3: *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

A.3 can be assessed by questions which involve an "if and only if" statement or by questions which naturally involve a proof by contrapositive or proof by contradiction.

Excellent	Exemplary proof which demonstrates full comprehension of the fundamentals of logic. The chosen strategy for the proof is natural, well motivated, and effective. Student has a clear understanding of what constitutes the converse or contrapositive statement. Mathematical and English language is highly articulate.
Very Good	Cogent proof which demonstrates good comprehension of the fundamentals of logic. The chosen strategy for the proof is apparent and effective. Student has a good understanding of what constitutes the converse or contrapositive statement. Mathematical and English language is easily understandable.
Satisfactory	Understandable proof which demonstrates reasonable comprehension of the fundamentals of logic. The chosen strategy for the proof is recognizable and mostly effective. Student has an understanding of what constitutes the converse or contrapositive statement. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Incomplete proof which demonstrates a partial comprehension of the fundamentals of logic. The chosen strategy for the proof has potential. Proof shows an indication of some comprehension of the pertinent mathematical definitions. Student indicates a partial understanding of what constitutes the converse or contrapositive statement. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written proof which demonstrates little or no comprehension of the fundamentals of logic. The chosen strategy for the proof is unclear and/or ineffective. Student does not demonstrate an understanding of what constitutes the converse or contrapositive statement. Errors are striking. Mathematical and English language is unclear.

Rubric for 401, SLO B.1: *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

B.1 will be naturally be assessed in most exam questions.

Excellent	Exemplary proof, with full justification for each step and the logic of argument flows naturally. The chosen strategy for the proof is natural, well motivated, and effective. Proof shows full comprehension of the pertinent mathematical definitions. Mathematical and English language is highly articulate.
Very Good	Cogent proof, with most key steps clearly justified. The chosen strategy for the proof is apparent and effective. Proof shows good comprehension of the pertinent mathematical definitions. Mathematical and English language is easily understandable.
Satisfactory	Comprehensible proof, with justification for the essential steps. The chosen strategy for the proof is recognizable and mostly effective. Proof shows reasonable comprehension of the pertinent mathematical definitions. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Partial progress on the proof, only some essential steps are justified. The chosen strategy for the proof has potential. Proof shows an indication of some comprehension of the pertinent mathematical definitions. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written proof, essential steps lack justification. The chosen strategy for the proof is unclear and/or ineffective. Comprehension of the pertinent mathematical definitions is uncertain. Errors are striking. Mathematical and English language is unclear.

Rubric for 401, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements. Communicate well, orally and in writing, in an applied mathematics context.

SLO C.1 is assessed based on the clarity of the presentation of the students work in exams.

Excellent	Exemplary writeup where the mathematical and English language is highly articulate.
Very Good	Cogent writeup where the mathematical and English language is easily understandable.
Satisfactory	Comprehensible writeup where the mathematical and English language is decipherable.
Questionable	Incomplete writeup where the mathematical and English language is incomplete.
Unacceptable	Poor writeup where the mathematical and English language is unclear.

E.10 Rubrics Math 402

The following SLOs are assessed in Math 402, a required course for all mathematics student with concentration in Pure Mathematics.

A.1 *Calculus.* Demonstrate understanding of foundations, including knowledge of basic definitions and fundamental theorems. Apply calculus to understand the behaviour of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives and integrals.

A.3 *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

B.1 *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

C.2 *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

In Math 402, student performance in these areas is assessed by regular graded homeworks, 1-2 mid-semester exams, and a final exam or a final research project (including an oral presentation and written report).

A.1 can be assessed by asking students to verify uniform continuity of a function or uniform convergence of a sequence of functions defined on metric spaces using the formal ϵ-δ or ϵ-N definition.

A.3 can be assessed by questions which involve an "if and only if" statement or by questions which naturally involve a proof by contrapositive or proof by contradiction.

B.1 will be naturally be assessed in most exam questions.

C.1 is assessed based on the clarity of presentation of students work in exams of in a final research project.

C.2 will be assessed by asking instructors to aggregate the results from homeworks and examinations and assess whether students have sufficient preparation for a real analysis course at the graduate level (only students with concentration in Pure Mathematics will be evaluated).

The following rubrics will be used to determine student performance:

Rubric for 402, SLO A.1: *Calculus.* Demonstrate understanding of foundations, including knowledge of basic definitions and fundamental theorems. Apply calculus to understand the behaviour of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives and integrals.

A.1 can be assessed by asking students to verify uniform continuity of a function or uniform convergence of a sequence of functions defined on metric spaces using the formal ϵ-δ or ϵ-N definition.

Excellent	Exemplary ϵ-δ or ϵ-N proof, with full justification for each step and the logic of argument flows naturally. Choice of the threshold δ or N is well motivated and effective for the given problem. Mathematical and English language is highly articulate.
Very Good	Cogent ϵ-δ or ϵ-N proof, with most key steps clearly justified. Choice of the threshold δ or N is effective for the given problem. Mathematical and English language is easily understandable.
Satisfactory	Comprehensible ϵ-δ or ϵ-N proof, with justification for the essential steps. Choice of the threshold δ or N is effective for the given problem. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Partial progress on the ϵ-δ or ϵ-N proof, only some essential steps are justified. Some visible progress on selecting the choice of the threshold δ or N for the given problem. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written ϵ-δ or ϵ-N proof, essential steps lack justification. Choice of the threshold δ or N is unclear or is ineffective for the given problem. Errors are striking. Mathematical and English language is unclear.

Rubric for 402, SLO A.3: *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

A.3 can be assessed by questions which involve an "if and only if" statement or by questions which naturally involve a proof by contrapositive or proof by contradiction.

Excellent	Exemplary proof which demonstrates full comprehension of the fundamentals of logic. The chosen strategy for the proof is natural, well motivated, and effective. Student has a clear understanding of what constitutes the converse or contrapositive statement. Mathematical and English language is highly articulate.
Very Good	Cogent proof which demonstrates good comprehension of the fundamentals of logic. The chosen strategy for the proof is apparent and effective. Student has a good understanding of what constitutes the converse or contrapositive statement. Mathematical and English language is easily understandable.
Satisfactory	Understandable proof which demonstrates reasonable comprehension of the fundamentals of logic. The chosen strategy for the proof is recognizable and mostly effective. Student has an understanding of what constitutes the converse or contrapositive statement. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Incomplete proof which demonstrates a partial comprehension of the fundamentals of logic. The chosen strategy for the proof has potential. Proof shows an indication of some comprehension of the pertinent mathematical definitions. Student indicates a partial understanding of what constitutes the converse or contrapositive statement. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written proof which demonstrates little or no comprehension of the fundamentals of logic. The chosen strategy for the proof is unclear and/or ineffective. Student does not demonstrate an understanding of what constitutes the converse or contrapositive statement. Errors are striking. Mathematical and English language is unclear.

Rubric for 402, SLO B.1: *Proof writing.* Be able to write clear proofs which show comprehension of formal definitions, recognize hypotheses, and form logical conclusions. Work with fundamentals of logic, including mathematical statements, their negation, converses and contrapositives. Argue using the principle of induction. Disprove by finding counterexamples.

B.1 will be naturally be assessed in most exam questions.

Excellent	Exemplary proof, with full justification for each step and the logic of argument flows naturally. The chosen strategy for the proof is natural, well motivated, and effective. Proof shows full comprehension of the pertinent mathematical definitions. Mathematical and English language is highly articulate.
Very Good	Cogent proof, with most key steps clearly justified. The chosen strategy for the proof is apparent and effective. Proof shows good comprehension of the pertinent mathematical definitions. Mathematical and English language is easily understandable.
Satisfactory	Comprehensible proof, with justification for the essential steps. The chosen strategy for the proof is recognizable and mostly effective. Proof shows reasonable comprehension of the pertinent mathematical definitions. Errors are relatively minor. Mathematical and English language is decipherable.
Questionable	Partial progress on the proof, only some essential steps are justified. The chosen strategy for the proof has potential. Proof shows an indication of some comprehension of the pertinent mathematical definitions. Errors are significant. Mathematical and English language is incomplete.
Unacceptable	Poorly written proof, essential steps lack justification. The chosen strategy for the proof is unclear and/or ineffective. Comprehension of the pertinent mathematical definitions is uncertain. Errors are striking. Mathematical and English language is unclear.

Rubric for 402, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.
*C.1 is assessed based on the clarity of presentation of students work in exams of in a final research project.*In courses such as Math 402, written mathematical communication will likely be evaluated in student's proofs. Instructors should therefore use the Rubric for SLO B.1 to give overall rating to the student's cumulative body of work.

Rubric for 402, SLO C.2: *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.
C.2 will be assessed by asking instructors to aggregate the results from homeworks and examinations and assess whether students have sufficient preparation for a real analysis course at the graduate level (only students with concentration in Pure Mathematics will be evaluated).

Excellent	Student is unquestionably prepared for graduate courses in real analysis in most Ph.D. programs, including those which focus on measure theory, functional analysis, and other advanced topics over foundations. Instructor estimates that the student is prepared for courses with a similar level of sophistication in other subjects. The body of graded work demonstrates an extraordinary intellect and work ethic. Instructor would support the student's admission into almost all Ph.D. programs without reservation.
Very Good	Student is likely prepared for graduate courses in introductory real analysis in most Ph.D. programs offered in the country, including those which treat measure theory, functional analysis, and other advanced topics. Instructor estimates that the student ought to be prepared for courses with a similar level of sophistication in other subjects. The body of graded work demonstrates a strong intellect and work ethic. Instructor would support the student's admission into the majority of Ph.D. programs without reservation.
Satisfactory	Student is likely prepared for the rigors of graduate school and the chances of success in introductory real analysis courses found in most Master's programs and some Ph.D. programs are good. Instructor estimates that the student is reasonably well prepared for courses in other subjects. The body of graded work demonstrates a good intellect and work ethic. Instructor would support the student's admission into most Master's programs and some Ph.D. programs.
Questionable	Preparation for real analysis at the graduate level is unclear. Instructor is unsure the student is prepared for graduate courses in other subjects. Evidence of the intellect and work ethic needed for graduate school is deficient. Instructor would have reservations about supporting the student's admission into Master's programs.
Unacceptable	Student is ill prepared for real analysis courses beyond Math 402. Instructor doubts the student is prepared for graduate courses in other subjects. Evidence of the intellect and work ethic needed for graduate school is inadequate. Instructor would not support the student's admission into graduate programs.

E.11 Rubrics Math 471

The following SLOs are assessed in Math 471, a required course for all mathematics student with concentration in Computational Mathematics.

B.4 *Scientific Computation.* Use computing tools for scientific computation. Implement numerical techniques to solve mathematical problems. Be able to use shared and distributed memory parallel computing platforms. (B.4)

C.1 *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements. (C.1)

C.2 *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

In Math 471, student performance in these areas is assessed by several computing projects, as well as presentation and/or individual meetings with the instructor for SLO C.2.

B.4 will be assessed in the following manner. The "use of computing tools for scientific computation" will be assessed by asking the students to do programming assignments in a modern scientific computing language (e.g., Python, Fortran, or C/C++). Some of these assignments will involve parallel implementations on a large-scale computer. The ability to "implement numerical techniques to solve mathematical problems" will be assessed in a variety ways. Students will be asked to (1) implement an iterative method and discuss its convergence properties, (2) implement a finite difference approximation of a partial differential equation model (e.g., the Laplace, Wave or Heat equation) and discuss its accuracy and stability properties, and/or (3) implement a numerical approximation of a time dependent system of ordinary differential equations (e.g., a model for N-body interaction) and discuss its accuracy and stability. The ability to "use shared and distributed memory parallel computing platforms" will be assessed by having one substantial shared memory computing homework assignment, and one substantial distributed memory programming homework assignment.

C.1 will be assessed using the student-written reports, in-class presentations, and/or through student instructor interaction during the computer laboratory sessions.

C.2 will be assessed using in-class presentations and/or through individual student-instructor interaction in office hours (only students with concentration in Computational Mathematics will be evaluated).

The following rubrics will be used to determine student performance:

Rubric for 471, SLO B.4: *Scientific Computation.* Use computing tools for scientific computation. Implement numerical techniques to solve mathematical problems. Be able to use shared and distributed memory parallel computing platforms.

Excellent	Exemplary programming skill shown with implementing, verifying, and parallelizing scientific algorithms, in serial, shared memory, and distributed memory settings. Demonstrated a clear understanding of the chosen differential equation model(s), and full understanding of how to measure their accuracy and stability properties.
Very Good	Good programming skill (with no errors) shown with implementing, verifying, and parallelizing scientific algorithms, in serial, shared memory, and distributed memory settings. Demonstrated a mostly clear understanding of the chosen differential equation model(s), and ability to measure their accuracy and stability properties.
Satisfactory	Ability (with only minor errors) to implement, verify, and parallelize scientific algorithms, in serial, shared memory, and distributed memory settings. Demonstrated (with only minor errors) understanding of the chosen differential equation model(s), and ability (with only minor errors) to measure their accuracy and stability properties.
Questionable	Partial ability (with occasional large errors) to implement, verify, and parallelize scientific algorithms, in serial, shared memory, and distributed memory settings. Demonstrated only partial understanding of the chosen differential equation model(s), and partial ability to measure their accuracy and stability properties. Few large errors present.
Unacceptable	Poor ability (with many large errors) to implement, verify, and parallelize scientific algorithms, in serial, shared memory, and distributed memory settings. Demonstrated (with many large errors) poor understanding of the chosen differential equation model(s), and poor ability to measure their accuracy and stability properties.

Rubric for 471, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

Excellent	Exemplary reports where the mathematical and English language is highly articulate.
Very Good	Cogent reports where the mathematical and English language is easily understandable.
Satisfactory	Comprehensible reports where the mathematical and English language is decipherable.
Questionable	Incomplete reports where the mathematical and English language is incomplete.
Unacceptable	Poor reports where the mathematical and English language is unclear.

Rubric 471, for SLO C.2: *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

Excellent	Student is unquestionably prepared for graduate courses in scientific computing or for a profession in scientific computing. The body of graded work demonstrates an extraordinary intellect, work ethic, and understanding of distributed computing, numerical algorithm analysis and development. Computer codes are extremely clear and well organized, and output extremely well presented.
Very Good	Student is likely prepared for graduate courses in scientific computing or for a profession in scientific computing. The body of graded work demonstrates a strong intellect, work ethic, and good understanding of distributed computing, numerical algorithm analysis and development. Computer codes are clearly written, well organized, and output well presented.
Satisfactory	Student is likely prepared for the rigors of graduate courses in scientific computing or for a profession in scientific computing. The body of graded work demonstrates a good intellect, work ethic, and overall understanding of distributed computing, numerical algorithm analysis and development. Computer codes give correct results but are moderately well written, output is correct but not clearly presented.
Questionable	Preparation for scientific computing courses at the graduate level or a profession in scientific computing is unclear. Evidence of the intellect, work ethic, and understanding of numerical issues is deficient. Output from computer codes is not consistenly correct and not well presented.
Unacceptable	Student is not prepared for scientific computing courses at the graduate level or a profession in scientific computing. Student has little understanding of distributed computing, numerical algorithm analysis and development, results from numerical codes are often incorrect and presentation is unclear and inadequate. Work ethic is poor.

E.12 Rubrics Stat 345

The following SLOs are assessed in Stat 345, a required course for all statistics majors.

A.1 *Calculus.* Demonstrate an understanding of foundations, including knowledge of basic definitions and fundamental theorems. Apply calculus to understand the behavior of functions. Use the fundamental theorem of calculus to compute definite and indefinite integrals. Apply definitions to compute limits, derivatives, and integrals.

B.6 *Probability and statistical modeling.* Be able to solve probability problems, with discrete and continuous univariate random variables, apply the Central Limit Theorem and understand sampling distributions. Be prepared to apply basic inferences for a single sample, including point estimations, confidence intervals, and hypothesis testing.

C.1 *Communication.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Stat 345, student performance in these areas is assessed by regular graded homeworks, 1-2 mid-semester exams, and a final exam.

A.1 is evaluated through problems related to derivations of cumulative distributions, expectations, calculate probabilities, and densities.

B.6 is assessed by probability problems related to sample spaces and events, axioms of probability, rules for probability calculation, and conditional probability, cumulative distributions, expectations, and densities. SLO B.6 is also assessed by problems related to sampling distributions, point estimation, confidence interval, and hypothesis testing procedures to a single sample.

C.1 is assessed using student-written assignments and exams.

The following rubrics will be used to determine student performance:

Rubric for 345, SLO A.1: *Calculus.* Understand and be able to use integration skills to derive cumulative distributions, expectations, and use derivative skills to obtain densities. *SLO A.1 is evaluated through problems related to derivations of cumulative distributions, expectations, calculate probabilities, and densities.*

Excellent	Exemplary solution which demonstrates full comprehension of the skill. The strategy follows directly from theoretical results. No errors.
Very Good	Cogent solution which demonstrates good comprehension of the skill. The strategy was apparent and effective. Errors are insignificant.
Satisfactory	Understandable solution which demonstrates reasonable comprehension of the skill. The strategy was recognizable and mostly effective.
Questionable	Incomplete solution which demonstrates partial comprehension of the skill. The strategy was potential effective. Errors are significant.
Unacceptable	Poor solution which demonstrates little to no comprehension of the skill. The strategy was unclear or ineffective. Errors are striking.

Rubric for 345, SLO B.6: *Probability and statistical modeling.* Be able to solve probability problems, with discrete and continuous univariate random variables, apply the Central Limit Theorem, and understand sampling distributions. Be able to understand basic inferences for a single sample, including point estimations, confidence intervals, and hypothesis testing.
SLO B.6 is assessed by probability problems related to sample spaces and events, axioms of probability, rules for probability calculation, and conditional probability, cumulative distributions, expectations, and densities. SLO B.6 is also assessed by problems related to sampling distributions, point estimation, confidence interval, and hypothesis testing procedures to a single sample.

Excellent	Exemplary solution which demonstrates full comprehension of the skill. The strategy follows directly from theoretical results. No errors.
Very Good	Cogent solution which demonstrates good comprehension of the skill. The strategy was apparent and effective. Errors are insignificant.
Satisfactory	Understandable solution which demonstrates reasonable comprehension of the skill. The strategy was recognizable and mostly effective.
Questionable	Incomplete solution which demonstrates partial comprehension of the skill. The strategy was potential effective. Errors are significant.
Unacceptable	Poor solution which demonstrates little to no comprehension of the skill. The strategy was unclear or ineffective. Errors are striking.

Rubric for 345, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements. *SLO C.1 is assessed using student-written assignments and exams.*

Excellent	Student has clearly interpreted solution in highly articulate statistical and English language.
Very Good	Student has interpreted solution in understandable mathematical/statistical and English language.
Satisfactory	Student has interpreted solution in decipherable mathematical/statistical and English language.
Questionable	Student has interpreted solution incompletely or misused in mathematical/statistical and English language.
Unacceptable	Student has misinterpreted solution completely or used unclear mathematical/statistical and English language.

E.13 Rubrics Stat 428

The following SLOs are assessed in Stat 428, a required course for all statistics majors.

B.5 *Statistical data analysis.* Demonstrate competence in data summarizing and plotting using a high-level statistical programming language (such as R, SAS, or Stata). Ability to implement statistical software analyses packages for designed experiments, sample surveys, and observational studies. Be able to correctly interpret the results, understand the limitations of the procedures, and understand the appropriate scope of conclusions.

C.1 *Communication.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

C.2 *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

In Stat 428, student performance in these areas is assessed by regular graded homework assignments, a midterm exams and/or quizzes, and a final exam or a final project.

B.5 will be evaluated through analysis problems related to MANOVA, principal components, discriminant analysis, classification, factor analysis, analysis of contingency tables including log-linear models for multidimensional tables, and logistic regression.

C.1 will be evaluated by student-written assignments and exams.

C.2 is assessed using student presentations and/or individual faculty/student meetings to discuss projects and materials (only Statistics majors will be evaluated).

The following rubrics will be used to determine student performance:

Rubric for 428, SLO B.5: *Statistical data analysis.* Demonstrate competence in data summarizing and plotting using a high-level statistical programming language (such as R, SAS, or Stata). Ability to implement statistical software analyses packages for designed experiments, sample surveys, and observational studies. Be able to correctly interpret the results, understand the limitations of the procedures, and understand the appropriate scope of conclusions.

B.5 will be evaluated through analysis problems related to MANOVA, principal components, discriminant analysis, classification, factor analysis, analysis of contingency tables including log-linear models for multidimensional tables, and logistic regression.

Excellent	Exemplary solution which demonstrates full comprehension of the skill. The strategy follows directly from theoretical results. No errors.
Very Good	Cogent solution which demonstrates good comprehension of the skill. The strategy was apparent and effective. Errors are insignificant.
Satisfactory	Understandable solution which demonstrates reasonable comprehension of the skill. The strategy was recognizable and mostly effective.
Questionable	Incomplete solution which demonstrates partial comprehension of the skill. The strategy was potential effective. Errors are significant.
Unacceptable	Poor solution which demonstrates little to no comprehension of the skill. The strategy was unclear or ineffective. Errors are striking.

Rubric for 428, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

C.1 is assessed using student-written assignments and exams.

Excellent	Student has clearly interpreted solution in highly articulate statistical and English language.
Very Good	Student has interpreted solution in understandable mathematical/statistical and English language.
Satisfactory	Student has interpreted solution in decipherable mathematical/statistical and English language.
Questionable	Student has interpreted solution incompletely or misused in mathematical/statistical and English language.
Unacceptable	Student has misinterpreted solution completely or used unclear mathematical/statistical and English language.

Rubric for 428, SLO C.2: *Preparation.* Preparation for graduate or professional schools, or for mathematical/statistical professions such as in science and engineering, teaching, data analysis, biostatistics, finance.

SLO C.2 is assessed using student-written homework assignments and exams or projects.

Excellent	Exemplary solution which demonstrates full comprehension of experiment design, commonly used regression models for continuous outcomes, and categorical data analysis methods. Be able to carry out data analysis correctly and write the analysis report without errors.
Very Good	Cogent solution which demonstrates good comprehension of experiment design, commonly used regression models for continuous outcomes, and categorical data analysis methods. Be able to carry out data analysis correctly and write the analysis report with insignificant errors.
Satisfactory	Understandable solution which demonstrates reasonable comprehension of experiment design, commonly used regression models for continuous outcomes, and categorical data analysis methods. Be able to carry out data analysis and write the analysis report without major errors.
Questionable	Incomplete which demonstrates partial comprehension of experiment design, commonly used regression models for continuous outcomes, and categorical data analysis methods. Data analysis results have major flaws and and analysis report has major errors.
Unacceptable	Poor solution which demonstrates little or no comprehension of experiment design, commonly used regression models for continuous outcomes, and categorical data analysis methods. Data analysis and result report have striking errors.

E.14 Rubrics Stat 445

The following SLOs are assessed in Stat 445, a required course for all statistics majors.

A.3 *Symbolic and abstract thinking* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

B.6 *Probability and statistical modeling.* Demonstrate an understanding of statistical models for standard designed experiments, sample surveys, and observational studies

C.1 *Communication.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

In Stat 445, student performance in these areas is assessed by regular graded homeworks, 2-3 mid-semester exams, and a final exam. Time permitting, short quizzes are sometimes given as well.

A.3 will be evaluated through problems related to multifactor ANOVA, principles of experimental design, analysis of randomized blocks, Latin squares, split plots, and random and mixed models.

B.6 will be evaluated through problems related to multifactor ANOVA, principles of experimental design, analysis of randomized blocks, Latin squares, split plots, and random and mixed models.

C.1 will be evaluated by student-written assignments and exams.

The following rubrics will be used to determine student performance:

Rubric for 445, SLO A.3: *Symbolic and abstract thinking.* Ability to give precise statements and construct logical arguments. Including statements of definitions, differentiating between hypotheses and conclusions of theorems, and understanding generalizations of basic concepts.

SLO A.3 is evaluated through problems related to multifactor ANOVA, principles of experimental design, analysis of randomized blocks, Latin squares, split plots, and random and mixed models.

Excellent	Exemplary solution which demonstrates full comprehension of the skill. The strategy follows directly from theoretical results. No errors.
Very Good	Cogent solution which demonstrates good comprehension of the skill. The strategy was apparent and effective. Errors are insignificant.
Satisfactory	Understandable solution which demonstrates reasonable comprehension of the skill. The strategy was recognizable and mostly effective.
Questionable	Incomplete solution which demonstrates partial comprehension of the skill. The strategy was potential effective. Errors are significant.
Unacceptable	Poor solution which demonstrates little to no comprehension of the skill. The strategy was unclear or ineffective. Errors are striking.

Rubric for 445, SLO B.6: *Probability and statistical modeling.* Demonstrate an understanding of statistical models for standard designed experiments, sample surveys, and observational studies.

SLO B.6 is assessed through problems related to multifactor ANOVA, principles of experimental design, analysis of randomized blocks, Latin squares, split plots, and random and mixed models.

Excellent	Exemplary solution which demonstrates full comprehension of the skill. The strategy follows directly from theoretical results. No errors.
Very Good	Cogent solution which demonstrates good comprehension of the skill. The strategy was apparent and effective. Errors are insignificant.
Satisfactory	Understandable solution which demonstrates reasonable comprehension of the skill. The strategy was recognizable and mostly effective.
Questionable	Incomplete solution which demonstrates partial comprehension of the skill. The strategy was potential effective. Errors are significant.
Unacceptable	Poor solution which demonstrates little to no comprehension of the skill. The strategy was unclear or ineffective. Errors are striking.

Rubric for 445, SLO C.1: *Communications skills.* Demonstrate effective written mathematical/statistical communication using precise, logically correct and clear statements.

SLO C.1 is assessed using student-written assignments and exams.

Excellent	Student has clearly interpreted solution in highly articulate statistical and English language.
Very Good	Student has interpreted solution in understandable mathematical/statistical and English language.
Satisfactory	Student has interpreted solution in decipherable mathematical/statistical and English language.
Questionable	Student has interpreted solution incompletely or misused in mathematical/statistical and English language.
Unacceptable	Student has misinterpreted solution completely or used unclear mathematical/statistical and English language.