

# Evaluating the Learning Experiences of Statistical Science Majors at Duke University

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## 1 Introduction

This document describes the steps that the Department of Statistical Science at Duke University will take to evaluate the learning experiences of its majors. It focuses on three items: the collection of data on student mastery and progress, the standards for honors theses, and the exit interview survey.

## 2 Collection of data to assess mastery and progress

The department will collect and evaluate data on students' mastery and progress related to each of five learning goals: intellectual foundations, core skills of the discipline, research skills, communication skills, and career preparation. The department will evaluate the data every year while the major is still relatively new (until 2010). After then, the department will conduct the assessments once every three years. The department can perform the assessments more frequently than every three years as needed. Such need arises when the Director of Undergraduate Studies hears from undergraduate instructors that they are not satisfied with the performance of their students in core courses for the major or in research.

### 2.1 Foundations and core skills

The intellectual foundations and core skills of the discipline are taught in three required courses for the major: STA 114, STA 121, and STA 122. STA 114 covers mathematical statistics, which is the foundation for future study. STA 121 covers regression analysis and its application to data analysis. STA 122 covers modern computational methods for data analysis and, for most majors, provides the tools needed to engage in research projects. To ensure that students master the material in these courses, the Department will take the steps outlined below. These steps will be coordinated by an undergraduate education committee comprising the Director of Undergraduate Studies and two regular rank faculty members appointed by the Chair.

#### 2.1.1 Assessment of STA 114

The purpose of STA 114 is to teach students about core concepts in probability-based, statistical inference. These concepts can be classified in five competency categories: 1) statistical modeling and sampling distributions, 2) likelihood theory and likelihood-based inference, 3) Bayesian reasoning, 4) point and interval parameter estimation, and 5) statistical testing. The course also prepares students for advanced statistical study, in particular for STA 122. Before classes start each semester, the Committee will inform instructors that these topics should be among those covered in STA 114. The Committee will review the final exams in

STA 114 to ensure that they include questions about the core topics.<sup>1</sup> These two actions will occur every year, regardless of whether there is an assessment.

The Committee will collect the final exams in STA 114. In years of assessment, at the end of the academic year the Committee will review the performance of majors to determine their level of mastery of the five competencies. Based on these assessments, the Committee will examine whether the educational objectives of the program are being adequately met. The Committee's assessments will be independent of and blind to the STA 114 instructors' assigned final grades. The Committee will prepare a short report on the mastery level of the current majors as a whole and present it to the Statistical Science faculty. If the overall performance of the majors is not satisfactory, the Committee will coordinate with the rest of the Statistical Science faculty to recommend and implement appropriate changes to STA 114.

For each of the five competency categories, each member of the Committee will grade each student's understanding on a three point scale, with 1 equal to "needs improvement," 2 equal to "adequate understanding," and 3 equal to "excellent understanding."

- Needs improvement means that the student has gained some knowledge about that concept, but not at a level adequate to learn the material in STA 122 and other advanced courses. This level will be determined by the Committee in collaboration with members of the regular rank faculty who teach STA 122 and advanced courses.
- Adequate understanding means that the student is ready for STA 122 and other advanced courses with respect to that concept, but there are some weaknesses in the student's preparation indicating lack of deep conceptual understanding.
- Excellent understanding means that the student is ready to excel in STA 122 and other advanced courses with respect to that concept. Typically, the student answers questions on that concept correctly or with only minor errors, such as careless mistakes or minor calculus errors.

Students' grades for a particular concept will be the average of the three Committee members' individual grades for that concept. Committee members will discuss any cases for which the three grades disagree to come up with a final determination.

The learning objectives of STA 114 will be deemed to be adequately met when the following hold.

- No major in statistical science scores a 1 in any category.
- No major in statistical science has an overall average across all categories below 2.5.
- No category has an overall average across majors below 2.5.

### 2.1.2 Assessment of STA 121

In the sequence of courses for the major, the purpose of STA 121 is to give students skills in data analysis and statistical modeling. The Committee will ensure that STA 121 includes a substantial data analysis final project as part of the assessments. These projects will require students to analyze real world questions by fitting regression models (including at minimum linear and logistic regressions) to complex multivariate data, emphasizing model selection, graphical model diagnostics, inference, and model interpretation. Before classes start each semester, the Committee will inform instructors that these topics must be covered in STA 121. These two actions will occur every year, regardless of whether there is an assessment.

The Committee will collect the final projects of majors in STA 121. In years of assessment, at the end of the academic year the Committee will review the final projects in STA 121 to determine majors' level of mastery on regression analysis. Based on these assessments, the Committee will examine whether the educational objectives of the program are being adequately met. The Committee's assessments will be independent of and blind to the STA 121 instructors' assigned grades. The Committee will prepare a short

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<sup>1</sup>However, the committee will not dictate how instructors teach the material, and what other topics the instructor chooses to cover.

report on the mastery level of the current majors as a whole and present it to the Statistical Science faculty. If the overall performance of the majors is not satisfactory, the Committee will coordinate with the rest of the Statistical Science faculty to recommend and implement appropriate changes to STA 121.

Each member of the Committee will read the majors' final projects and rate them on a scale of 1 - 5, where each score is as follows.

- For a 5, the final project used a statistical model appropriate for the question and data of interest, demonstrated careful checking of model diagnostics including influential points and residual plots, addressed issues of model selection including transformations and interactions, interpreted results correctly using inferential methods like interval estimation and testing, and made accurate conclusions about the question of interest.
- For a 4, the final project used a statistical model somewhat appropriate for the question and data of interest, interpreted results correctly using inferential methods like interval estimation and testing, and made accurate conclusions about the question of interest. The project did only one of the following: demonstrated careful checking of model diagnostics including influential points and residual plots, addressed issues of model selection including transformations and interactions.
- For a 3, the final project used a statistical model somewhat appropriate for the question and data of interest, interpreted results correctly using inferential methods like interval estimation and testing, and made accurate conclusions about the question of interest using that model. The project did not demonstrate careful checking of model diagnostics including influential points and residual plots and did not address issues of model selection including transformations and interactions.
- For a 2, the final project used a statistical model somewhat appropriate for the question and data of interest. There are serious problems with the interpretations of the analysis. The use of inferential methods like interval estimation and testing may have problems. There is no or inadequate model checking and no consideration of model selection including transformations and interactions.
- For a 1, the final project used a statistical model that was not appropriate for the data. There are problems with interpretations, inferential methods, model checking, and model selection.

Students' grade will be the average of the three Committee members' individual grades. Committee members will discuss any cases for which the three grades disagree to come up with a final determination.

The learning objectives of STA 121 will be deemed to be adequately met when the following hold.

- No major in statistical science scores below a 3.
- The overall average across majors is at least a 4.

## 2.2 Assessment of STA 122

In the context of the major, the purpose of STA 122 is to teach students to use Bayesian methods for statistical inference. Key concepts include Bayesian modeling and inference (including simulating and interpreting posterior distributions), techniques for building and estimating non-standard statistical models, and techniques for checking the fit of those models. Before classes start each semester, the Committee will inform instructors that these topics must be covered in STA 122. The Committee will ensure that STA 122 includes a data analysis final project or final exam as part of the assessments. The project or exam will require students to utilize Bayesian modeling and inference (including simulating and interpreting posterior distributions), techniques for building and estimating non-standard statistical models, and techniques for checking the fit of those models. These two actions will occur every year, regardless of whether there is an assessment.

The Committee will collect majors' projects or final exams from STA 122. In years of assessment, regardless of whether students complete a project or exam, the Committee will assess performance as follows.

At the end of the academic year, each member of the Committee will read the majors' final projects or exams and rate them on a scale of 1 - 5, where each score is as follows.

- For a 5, the student demonstrates proficiency in developing Bayesian models for applied problems, including models for the data and models for parameters; is able to write a computer program that samples from posterior distributions; is able to perform model diagnostics with Bayesian models; and, is able to perform model selection with Bayesian models.
- For a 4, the student demonstrates proficiency in developing Bayesian models for applied problems, including models for the data and models for parameters, and is able to write a computer program that samples from posterior distributions. The student demonstrates proficiency in only one of the following: model diagnostics or model selection in Bayesian models.
- For a 3, the student demonstrates that he or she can work with a Bayesian model for applied problems given the model specification and is able to write a computer program that samples from posterior distributions. The student demonstrates proficiency in at least one of the following: model diagnostics or model selection in Bayesian models.
- For a 2, the student demonstrates that he or she can work with a Bayesian model for applied problems given the model specification and is able to write a computer program that samples from posterior distributions. The student demonstrates proficiency in none of the following: model diagnostics or model selection in Bayesian models.
- For a 1, the student demonstrates that he or she can work with a Bayesian model for applied problems given the model specification. However, he or she struggles to write a computer program that samples from posterior distributions. The student demonstrates proficiency in none of the following: model diagnostics or model selection in Bayesian models.

Students' grade will be the average of the three Committee members' individual grades. Committee members will discuss any cases for which the three grades disagree to come up with a final determination.

The learning objectives of STA 122 will be deemed to be adequately met when the following hold.

- No major in statistical science scores below a 3.
- The overall average across majors is at least a 4.

## 2.3 Research skills

All majors are required to complete a research project under the supervision of a Statistical Science faculty member. Development and completion of this project serves as the primary way that majors improve their statistical research skills. Majors also learn research skills in upper level STA courses. Majors are required to take STA 190A and STA 190B, in which students discuss and present their research to other students and faculty.

In years of assessment, we will assess majors' research skills as follows.

- By the end of each academic year, each faculty research advisor will inform the Committee about his or her student's progress towards developing research skills and completing the research project. This report will include answers to the following questions:
  - Does the student have a well defined research topic?
  - When appropriate, has the student demonstrated ability to perform exploratory data analysis in ways that lead to better fitting models?
  - When appropriate, has the student demonstrated ability to discuss model fitting strategies with clear comprehension?

- When appropriate, has the student demonstrated ability to develop their own models for the data analysis question at hand?
  - When appropriate, has the student demonstrated ability to write computer programs for inferences?
  - When appropriate, has the student been able to interpret their model output correctly?
  - Please provide any further comments on the students' research skills or your answers to these questions.
- At the end of the academic year, the instructor(s) of STA 190A and STA 190B will inform the Committee about the students' skills in and abilities to engage in statistical research. The instructor will answer the same questions as in the previous bullet.
  - The Committee will evaluate the feedback from research advisors and STA 190 instructors to gauge the level of research skills of the current majors as a whole.
  - The Committee will prepare a short report on the research skills of the current majors as a whole and present it to the Statistical Science faculty at the end of each academic year. If the overall performance of the majors is not satisfactory, the Committee will coordinate with the rest of the Statistical Science faculty to recommend and implement appropriate changes to the statistical science program in order to improve students' research skills.

## 2.4 Communication skills

Majors have several opportunities to develop their communication skills. In STA 190A and STA 190B, students are required to give oral presentations in front of classmates and faculty. The instructor(s) of STA 190A and STA 190B work with students on their communication skills. Majors also are required to write a manuscript describing their research. The student's faculty research advisor helps students to improve their writing skills.

In years of assessment, to assist the Committee in assessing the communication skills of majors, the faculty research advisors will discuss writing skills in their reports to the Committee. Advisors will answer the following questions.

- Can the student logically organize a research paper? That is, does the student write in a way that presents ideas in logical sequence?
- Does the student make sure to justify all non-obvious claims with mathematical or empirical evidence?
- Does the student write paragraphs that have clear topic sentences?
- Does the student define all notation when writing?
- What aspects of the student's writing are best? What aspects of the student's writing need most improvement?
- Please provide any further comments on the students' writing skills or your answers to these questions.

The instructor(s) of STA 190A and STA 190B will discuss the presentation skills of the majors in their reports to the Committee. The instructor(s) will answer the following questions.

- Can the student logically organize a research talk? That is, does the student present ideas in logical sequence?
- Does the student make sure to justify all non-obvious claims with mathematical or empirical evidence?
- Does the student present clear slides without too much material?

- Does the student define all notation when presenting?
- Does the student use good presentation skills, including facing the audience, speaking clearly and deliberately, keeping within assigned time limits?
- What aspects of the student's presentation skills are best? What aspects of the student's presentation skills need most improvement?
- Please provide any further comments on the students' presentation skills or your answers to these questions.

The Committee will summarize this feedback and include in its reports to the Statistical Science faculty the overall percentages for each yes or no question. The Committee also will report on the trends in the best and worst skills questions. The Committee will deem that the program is adequately achieving its objectives if each yes/no question has a majority of yes answers. The Committee will suggest recommendations about changes in the way we teach communication skills when this is not the case.

## 2.5 Career preparation

Majors in statistical science get advice about careers via interactions with faculty and graduate students in the department. The DUS will ensure that all major advisors discuss career options with prospective majors. To evaluate the success of this counseling, the DUS will ask students about career discussions in the exit survey (see Section 4).

For each major, the DUS will maintain a professional portfolio that includes the materials from STA 114, STA 121, STA 122, and the research project. The portfolio can also include substantial works from upper level courses. This portfolio will be useful for faculty writing letters of recommendation, as well as to track the performances of cohorts of majors over time.

## 3 Standards for honors theses

The Department of Statistical Science has several requirements for graduation with distinction. These are publicly displayed on our departmental web site. To graduate with distinction a student must write a research paper (thesis) demonstrating significant independent work in statistical science. The paper must be completed six weeks prior to graduation. The student must present the paper orally during the month before graduation. This presentation is open to the public. The student also must meet eligibility criteria based on grade point average.

Each candidate has a committee of three faculty members. The committee evaluates the candidate's paper and oral presentation for quality of intellectual content, quality of writing/speaking, and originality. The committee determines whether distinction will be awarded.

To determine if an eligible candidate merits graduation with distinction, the committee members evaluate the candidate's paper as if it was submitted for publication and they were its reviewers. Two or more members of the Committee must believe that the paper is worthy of publication in a reputable statistical or applied journal. Two or more members of the Committee also must believe that the candidate conveyed her or his ideas clearly in the oral presentation.

The department hopes that at least 25% of its majors will earn graduation with distinction. If this is not the case, we will evaluate information from the exit interviews to see if and how we can change the program to encourage more honors theses.

## 4 Exit interview

At the end of the student's graduation year, the department will administer a final exit interview of majors. The interviews are conducted by the DUS and any regular rank faculty authorized by the DUS. The exit

interview questionnaire will include the following questions, as well as others that the DUS thinks will inform the management of the major program. These interviews will happen every year.

1. Please comment on the advising you received as a statistical science major. What aspect of it was most useful? What aspect was least useful? What could be improved?
2. Please comment on how you completed the requirements of the major. Were there enough courses offered that you wanted to take? What courses do you wish were offered? Was the sequence of the courses that you took appropriate? Are there any difficulties with course sequencing? Was the research experience valuable? How could we improve the experience? Do you feel like you would be able to reasonably analyze a complex data analysis question in the future?
3. Please comment on particular courses. Which courses best prepared you for your future plans and why? Which courses were least useful and why? Which courses most improved your understanding of the field and why? Which courses did the least to improve your understanding? Which ones did you leave most confused about the material? Are the courses synchronized appropriately, so that you have a chance to learn all the background material for upper level classes before you take them? Or, was there material not covered in lower level classes that you needed for upper level classes?
4. Did you pursue a senior honors thesis? If so, why did you pursue it? Would you recommend this to other statistical science majors? What was the most enjoyable aspect of the honors thesis? What was the least enjoyable aspect? If you did not pursue an honors thesis, why not? Looking back, are you pleased with that decision? Is there anything about your program of study that, if changed, might have led you to pursue an honors thesis?
5. What are your plans for post-undergraduate? Did you secure employment that is likely to use statistical analysis or thinking? Do you feel that you got adequate advising about careers or internships from the Department?
6. Are there other aspects of the major or the Department that you want to comment on? What did you especially like? What do you wish was different? Did you enjoy being a statistical science major? If you could return to your sophomore year, would you again choose statistical science as your major?