Statistics Program Area Study Group Report

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Introduction

The world is awash in data, and there is a growing demand for decisions informed by data. In colleges and universities, request for statistics courses and statistics degrees has increased substantially. From 2005 to 2011, there has been a 40% increase in demand for elementary statistics and probability courses increased 40%; and undergraduate statistics degrees increased 62%. These and additional sta

substantially from late 20th century norms. The American Statistical Association makes, and will continue to make, its own recommendations about statistics curricula [2].

Program recommendations

c. ***For students who want a minor or concentration in statistics.*** Work with other departments as needed, to identify and/or offer coherent sets of courses for a minor or concentration in statistics

work in another field besides statistics.

In a college or university without a statistics department, the mathematics department should undertake to provide a minor or concentration in statistics. A mathematics department need not offer all the courses involved in such a minor, but the department should lead in organizing coherent sets of courses, in statistics and in allied areas, for at least two categories of students:

minor/concentration in statistics and then build from there.

d. ***For students with mathematics majors who want a minor or concentration in statistics.*** Provide appropriate advising to these students, depending upon whether the goal is to prepare for a graduate degree in statistics or an initial employment in data analysis after the undergraduate degree.

In addition to an introductory applied statistics course, the student should have a two-semester probability and mathematical statistics
mentioned above would be also useful.

Essential mathematics courses include multivariate calculus and applied linear algebra. Some work in computer programming and database management would be helpful. Real analysis will give students a solid preparation for graduate work in theoretical statistics. Encourage students interested in applied statistics to pursue substantial study in a field where statistics is used extensively.

One of the main paths to a good career with a substantial component of data analysis comes from having a major in a subject area, such as biology, and a minor or even a double major in statistics. Thus we encourage mathematics departments to work with colleagues in other departments to identify coherent interdisciplinary programs of study. Doing so may require a mathematics department to offer some courses in statistical analysis that rely on an introductory applied statistics course, but go on to address more advanced techniques in more general forms. Such courses should include both enough theory that students can assess when a technique is applicable, and exposure to fairly complex, realistic, applications.

Courses needed; some new

Statistics is the science of data focused on obtaining useful information from data. Students in all statistics courses should be encouraged to fit the ideas and methods they are learning into that overview. The variability in the data includes evidence about the patterns that form the useful

appropriate choices among multiple possible patterns that could be used.

Most mathematics departments have been offering at least an elementary statistics course and a two-semester sequence of probability and mathematical statistics. It is important to continue offering such courses that are meeting the needs of the students.

a. **An introductory applied statistics course focusing on data analysis and following the various guidelines as described in the report from the Course Area Report on Statistics [3].**

We recommend that a mathematics department use the Course Area Report on Statistics [3] to consider whether its current introductory course would be appropriate as an introduction to data

analysis for mathematics majors. Perhaps it would be more appropriate to develop a course similar to this for the particular audience of students from mathematics and math-intensive disciplines, which might be able to get to some more exciting and deeper data analysis in one

courses.

Students heading for graduate school in statistics, and all students who want to understand the theory of statistics, need a solid foundation in probability at the level usually taught in the typical junior-level post-calculus probability course. This allows students to understand how to build and interpret probability models and to understand how the standard statistical inference techniques are based on sampling distributions of statistics. As we broaden our repertoire of statistical techniques to include Bayesian methods, resampling methods, and the various techniques used with Big Data, it is even more important for students to understand the foundations well enough to compare and contrast the meaning of the results of analyses from these techniques.

members to work on this, give them adequate credit for their work as service to the department, and make clear the expectation that they will become/stay involved in the conversations in professional associations about undergraduate statistical education.

Needed skills and recommendations for delivery

In 2000 the American Statistical Association approved curriculum guidelines for undergraduate programs in statistical science [2], which covers majors in statistical science departments and minors or concentrations in other departments. Five necessary skills were identified for effective statisticians. Here is the ASA list:

1. *Statistical*: Graduates should h5 4 4(n] TnETBA 4a l3u411 156BT 0 0 1 36(n] Tn

pedagogy and assessment to the typical statistics courses of earlier times. References at the end of this report include several main papers contributing to and documenting these changes. The following non-exhaustive list of recommendations is paraphrased mainly from the ASA Curriculum Guidelines [2] and the GAISE Report [4].

1. Stress conceptual understanding more than knowledge of particular procedures.
2. Emphasize statistical literacy and develop statistical thinking.
3. Use real data and authentic applications and require students to communicate results in context. Students should be expected to communicate orally and visually, as well as in written form.
4. Encourage synthesis of theory, methods, and applications.
5. Include experience with statistical computing, both to explore concepts and to analyze data.
6. Use technology of various types to support conceptual understanding, active learning, and communication among students and between students and the instructor.
7. Provide opportunities for active learning, in contrast to traditional lecture format.
8. Use a variety of assessments designed to improve and measure student learning.

Why students should choose a statistics minor or concentration

In a college with no statistics department, the mathematics advisers should be available to offer information to all students who want a statistics minor or concentration. Students majoring in mathematics, as well as those in many other areas, have good reasons to choose a minor or concentration in statistics. The mathematics advisers should be ready to recommend which of the courses available in their institution are most useful for each of these paths.

A statistic

Courses in multivariate statistics, regression, and experimental design are often included in statistics minors or concentrations. Mathematical statistics may also be included as an option. Other courses now often mentioned include time series, categorical data analysis, non-parametric statistics, and survey sampling, along with a capstone course. Most of these courses use only algebra; the exceptions are multivariate statistics, which may use linear algebra, and mathematical statistics, which

somewhat, except for elite universities and colleges who are less concerned with the cost of the current delivery model. Even if MOOCs do not drastically change education, they will lead to more flipped classrooms.

The arrival of Big Data has just begun to affect undergraduate statistics education. At a minimum there will be a need to acknowledge its presence in the introductory applied statistics course. Because traditional inferential methods cannot be used to analyze such data, there will be a need to develop additional electives, in addition to the Data Mining course already found at some institutions. One such Data Science course at Smith College [10] was recently taught as a Five-College course. Here is its description:

> provides a practical foundation for students to compute with data, by participating in the entire data analysis cycle (from forming a statistical question, data acquisition, cleaning, transforming, modeling and interpretation). This course will introduce students to tools for data management, storage and manipulation that are common in data science and will apply those tools to real scenarios. Students will undertake practical analyses using real, large, messy datasets using modern computing tools (e.g. R, SQL) and learn to think statistically in approaching all of these aspects of data analysis.

Other possible special-topic elective course topics all computer-intensive include Bayesian statistics, simulation and optimization, and advanced graphics for visualization. Courses related to the analysis of Big Data are likely to become part an interdisciplinary joint minor with other areas, such as computer science and operations research.

have placed in the website which accompanies this report [6]. The same website contains references to two statistics-

Finally, we acknowledge that portions of this report will be dated as soon as it is published. Hence we encourage individuals interested in how much and what statistics should be taught in a college or university departments of mathematics or mathematical sciences to be aware of these four important associations promoting collaboration and innovation in undergraduate statistical education:

American Statistical Association (ASA) http://www.amstat.org/education/index.cfm and http://www.amstat.org/sections/educ/

Consortium for the Advancement of Undergraduate Statistics Education (CAUSE) https://www.causeweb.org/

International Association for Statistical Education (IASE), http://iase-web.org/

Mathematical Association of America Special Interest Group on Statistics Education (Stat-Ed SIGMAA), http://sigmaa.maa.org/stat-ed/

References

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2. http://www.amstat.org/education/curriculumguidelines.cfm. First published in 2000 and due to be updated in 2015. The 2000 guidelines will continue to be archived on this website.

3. C
(A separate report in this current guide.) (2014).

4. dorsed by the American Statistical Association.) (2005). http://www.amstat.org/education/gaise/

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http://www.amstat.org/publications/jse/v10n2/garfield.html

8. *The Proceedings of the Sixth International Conference of Teaching Statistics* (2002).
http://www.stat.auckland.ac.nz/~iase/publications/1/3f1_albe.pdf

9. (2004). http://www.maa.org/programs/faculty-and-departments/curriculum-department-guidelines-recommendations/cupm/cupm-guide-2004

10. http://sophia.smith.edu/blog/4cbc/2013/04/01/mth-292-data-science/