RESEARCH METHODS FOR SCIENCE

A unique introduction to the design, analysis, and presentation of scientific projects, this is an essential textbook for undergraduate majors in science and mathematics.

The textbook gives an overview of the main methods used in scientific research, including hypothesis testing, the measurement of functional relationships, and observational research. It describes important features of experimental design, such as the control of errors, instrument calibration, data analysis, laboratory safety, and the treatment of human subjects. Important concepts in statistics are discussed, focusing on standard error, the meaning of p-values, and the use of elementary statistical tests. The textbook introduces some of the main ideas in mathematical modeling, including order-of-magnitude analysis, function fitting, Fourier transforms, recursion relations, and difference approximations to differential equations. It also provides guidelines on accessing scientific literature, and preparing scientific papers and presentations. An extensive instructor's manual containing sample lessons and student papers is available at www.cambridge.org/Marder.

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Preface

This book accompanies a one-semester undergraduate introduction to scientific research. The course was first developed at The University of Texas at Austin for students preparing to become science and mathematics teachers, and has since grown to include a broad range of undergraduates who want an introduction to research. The heart of the course is a set of scientific inquiries that each student develops independently. In years of teaching the course, the instructors have heard many questions that students naturally ask as they gather data, develop models, and interpret them. This book contains answers to those most common questions.

Because the focus is on supporting student inquiries, the text is relatively brief, and focuses on concepts such as the meaning of standard error, p-values, and deterministic modeling. If a single statistical test, such as χ^2, is adequate to deal with most student experiments, the text does not introduce alternatives, such as ANOVA, even if they are standard for professional researchers to know.

The mathematical level of the book is intermediate, and in some places presumes knowledge of calculus. It could probably be used with students who don't know calculus, skipping these sections without great loss.

There is an instructor's manual that describes daily activities for a 14-week class that meets two hours per week in a classroom and two hours per week in a lab. It is available at www.cambridge.org/Marder. The classroom sessions are not lectures covering the material in these chapters, but instead consist in activities focusing on basic concepts. The text in many cases contains more complete explanation than there is time to deliver in class.

The basic idea for the class and hence of this book is due to David Laude, Professor of Chemistry and Associate Dean for Undergraduate Education at UT Austin. He had two essential insights: First, the way to learn about scientific research is actually to do some. Second, it doesn't matter if research results are not new so long as they are new to the person who does them. The ingenious order

"BE CURIOUS!!" in the first inquiry assignment (page 15) comes from his first assignment in the first semester he taught it.

Many other course instructors have contributed. Mary Walker and Denise Ekberg both brought in course elements because of their backgrounds that span scientific research and secondary teaching. They emphasized the importance of procedures to ensure student safety, and also insisted on rubrics and checklists so that students received clear messages during an otherwise free-wheeling class of what was acceptable, what was forbidden, what was desired, and what was discouraged. Thomas Hills emphasized the importance of open questions. Many teaching assistants have also contributed to the course content, particularly Sed Keller, who wrote the first draft of the appendix on use of spreadsheets.

For many years, I have co-taught the class with Pawan Kumar, Professor of Astronomy, and Dan Bolnick, Associate Professor of Integrative Biology. Pawan Kumar helped create all the homeworks, and insisted we find ways to tie research on closed questions back into research on areas of social concern. Dan Bolnick gently prodded me to throw out all previous approaches to statistics, and make use of examples from biology that worked much better.

Finally, I would like to thank Mary Ann Rankin, Dean of the College of Natural Sciences, who insisted passionately from the start that future teachers in our UTeach program learn about scientific research, and has provided every form of support needed to help the class grow.

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