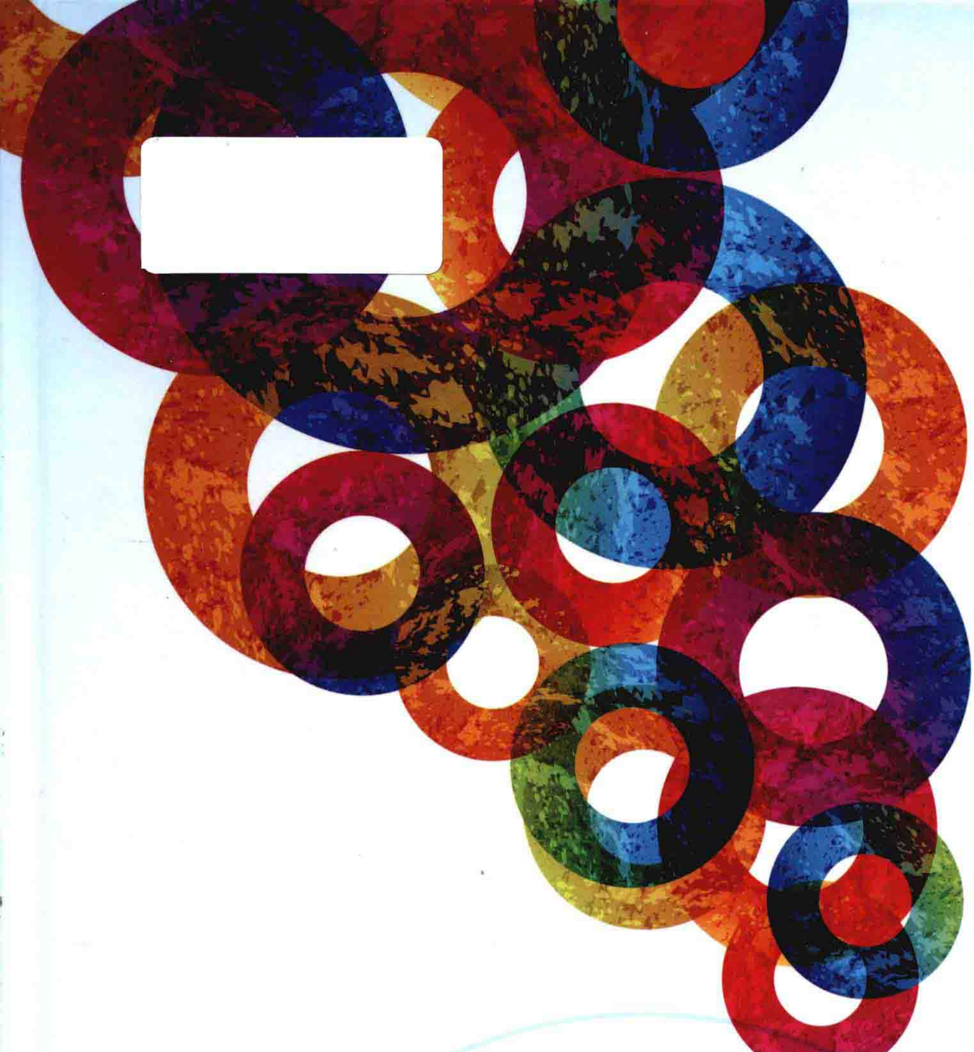

RESEARCH METHODS
FOR ENGINEERS

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Research Methods for Engineers

Learn how to plan for success with this hands-on guide to conducting high-quality engineering research.

Plan and implement your next project for maximum impact
Step-by-step instructions that cover every stage in engineering research, from the identification of an appropriate research topic through to the successful presentation of results.

Improve your research outcomes
Discover essential tools and methods for producing high-quality, rigorous research, including statistical analysis, survey design and optimization techniques.

Research with purpose and direction
Clear explanations, real-world examples and over 50 customizable end-of-chapter exercises, all written with the practical and ethical considerations of engineering in mind.

A unique engineering perspective
Written especially for engineers, and relevant across all engineering disciplines, this is the ideal book for graduate students, undergraduates, and new academics looking to launch their research careers.

David V. Thiel is a Professor and Deputy Head (Research), Griffith School of Engineering, Griffith University, Australia. He has been teaching engineering research methods to students for several years, has managed numerous industry research and development contracts, is the author of over 120 papers published in international journals and is a Fellow of the Institution of Engineers Australia.

Preface

This book is unashamedly idealistic. It aims first to convey to engineers and engineering undergraduates interested in conducting research a reminder of the fundamental principles of engineering, and then to explain the requirements of conducting excellent, publishable research which will benefit humankind. A number of issues distinguish engineering research from other forms of scientific research. These issues include the dedication of engineering to the betterment of humankind, an acknowledgement of the codes of ethics regulating all engineering activities, the use of engineering standards to ensure quality and acceptable research outcomes and a conviction that sustainability is now a major engineering imperative.

The book is based on a lecture course delivered at Griffith University in the engineering school for coursework master's degree students both on and off campus. The initial concept for the course was developed by Professor Sherif Mohammed at Griffith University. This was revised substantially by the author and then further modified by other faculty staff involved in delivery of the course. The course has also been substantially improved by the students themselves – many of these students have English as a second or third language. To accommodate this, the book contains many starting hints particularly aimed at these students, so that students can rapidly progress without resorting to direct copying from other sources.

The course required the students to submit three written assignments using engineering journal format (a template was provided) and appropriate structure and language. All three assignments were based on a published journal research paper selected by the student individually. The first assignment required the students to write a literature review based on the journal paper and additional relevant papers published more recently. The second assignment was a summary of the research methods used in the selected paper, and was combined with the Assignment 1 literature review, but modified in line with the instructor's feedback. The third assignment built on the previous two assignments and instructor feedback, but had the additional requirements of including a research plan, the research team, data analysis and data presentation. The students were required to create an ideal outcome graphically and to describe the statistical analysis to be used to verify their conclusions resulting from their research outcomes.

The on-campus version of the course involved two classroom hours per week – one lecture and one workshop. Students were required to prepare for the workshop using topics presented to them before the class. Their workshop sheets were submitted at the end of each workshop for feedback. All workshop sheets were directly relevant to the preparation of their assignments. Commonly students were required to comment on each other's work, to present their work and to modify their workshop sheets in line with the class and lecturer feedback. Some of the exercises in this book were used for this purpose.

The off-campus course was run in a similar manner, with students having access to the recorded lectures and the Powerpoint presentations from the lectures. Students were also required to prepare the same workshop sheets, and comment on each other's work using email. The feedback from the instructor and other class members was used to guide the students to improve their methodology and written work for their next submission – either the next workshop or the next assignment.

For both on-campus and off-campus delivery, the student feedback was excellent. As with all courses, the more effort that students put into working with the material, the greater the rewards. The course taught even those students who were not aiming to undertake research work or a research career to look for academic research rigour in the published articles they read, and so to distinguish between solid research outcomes and other reports. It also provided guidelines for report writing - a common task in commercial and industrial workplaces. These skills are beneficial to an engineering career.

All engineering disciplines can engage with the material in the book as the students self-select papers to review which are relevant to their specific discipline. Readers will quickly note that many of the exercises rely heavily on a fundamental understanding of a student's particular engineering discipline. Students who took the course without this fundamental knowledge of a discipline struggled significantly.

I always enjoyed giving these classes. I hope readers enjoy this book and can make a positive contribution to humanity through their engineering expertise and research outcomes.

In conclusion, I would like to thank my fellow academics in the Griffith School of Engineering and the students who have provided me with excellent motivation to teach the course. Most importantly, I express my thanks to my lovely family who have always provided me with wonderful support.

David Thiel

An introductory note for instructors

This course was run at master's degree level at Griffith University for engineering graduates. For convenience, the book refers to the intended readers of the book as novice researchers, regardless of their status. While the first course was delivered to graduate students, some universities have introduced a research methods course in their engineering undergraduate degree programmes. When teaching the course, we assume the following knowledge gained from undergraduate engineering studies:

- A basic understanding of the fundamental concepts and language in a relevant engineering discipline;
- Some experience in laboratory experimentation including the application of mathematical laws to plot and understand sets of results;
- A basic understanding of measurement theory, errors in measurements and statistics;
- The efficient use of a method of analyzing and plotting data (e.g. Matlab or MS Excel).

As a number of the topics in the book are covered in undergraduate engineering degree programmes, the content of this book provides a concise introduction to these concepts. The reader should look to more comprehensive texts for a more careful, detailed analysis or to gain an understanding of the scientific background behind the use of these techniques. Each chapter includes a small list of references. More importantly, readers are given some keywords to conduct searches for further information on any topic.

Many of the techniques outlined in the book are very quick and simple to implement using electronic tools. It is a five minute task for students:

- To plot a set of experimental data points as points and to include the line of best fit (usually a straight line), calculate the equation and the correlation coefficient;
- To find published scientific papers using a keyword search for a literature review.

A failure to do these very simple things in a research report, thesis or research paper suggests to the reader that the author is not a competent researcher. Novice researchers must gain good habits if they are to become efficient, rigorous members of a research team.

Undergraduate engineering students can be taught good experimental and writing habits if the classroom materials are presented in a professional manner. The class laboratory notes should be supplied in the form of a research project outline (see Figure 3.1) complete with an introduction, background theory, measurement techniques and suggested data analysis. There should be adequate references to the textbook and other published papers. Instructors can set an excellent example through this approach, and also demand a similar level of reporting.

Contents

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Introduction to engineering research

1.1 Why engineering research?

The disciplines of engineering are all described as the application of science to realistic systems which benefit humankind [1]. Engineering research is therefore based on the principles of scientific research which, in turn, are based on the scientific method, in which observations (experiments), theories, calculations and models are derived from the existing body of scientific knowledge and verified independently by others who are experts in the field [2–4]. This latter process is called 'peer review'. While this formal review by peers is not foolproof, it constitutes the best method of validation and verification of research results. Engineering research is based on precisely the same scientific method; however, the research is directed toward the practical application of science to products, services and infrastructure.

Most research starts with a hypothesis; that is, a statement which can be either proved or disproved. In most cases it is easier to disprove a hypothesis because only one counter example is required to discredit the idea. To prove a hypothesis, it is necessary to exhaustively examine every possible case and make sure the hypothesis applies. Often this results in the creation of limiting conditions. The conclusion becomes slightly modified in that the hypothesis is valid providing certain conditions are met. A full evaluation of a hypothesis may take many years without a conclusive resolution.