A TEXTBOOK

IN THE

PRINCIPLES OF SCIENCE TEACHING

BY

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TO

MY TEACHERS

ESPECIALLY THOSE WHO HAVE HELPED ME IN MY THINKING
AND INSPIRED IN ME AN ABIDING ENTHUSIASM FOR
SCIENCE AND THE TEACHING OF SCIENCE, THIS
BOOK IS GRATEFULLY DEDICATED

PREFACE

THIS book is intended primarily to be used in the instruction of young men and women who are preparing themselves in colleges and normal schools for careers as teachers of one or more of the natural sciences; but it is hoped that it will be scarcely less useful to science teachers now in service and to superintendents of school systems and principals of public and private secondary schools whose duties involve the direction and supervision of science instruction. It is thought also that the book contains much that will be of value to professors of the several natural sciences in colleges and normal schools, in helping them to impart to prospective teachers of their sciences the modern social viewpoint and the true scientific spirit that are so necessary for real success in teaching the sciences to boys and girls of high school age.

The volume is a natural outgrowth of a long career as high school teacher of science, high school inspector, and college teacher of education. It embodies the results of constant study of the natural sciences and of psychology, especially in its applications to science teaching and high school administration, carried on during the course of this career. It attempts to show in a concrete and practical way how the findings of modern experimental and educational psychology may be applied in science teaching. The first eleven chapters and the last one develop and formulate principles that are fundamental to all science training; the others are devoted to the explanation of principles and methods of teaching that are especially applicable to the several sciences of the high school curriculum. They contain also practical hints on the selection and organization of subject matter, the

planning of laboratories, and the choice of equipment in connection with science instruction.

There are several ways in which the book may be used in the instruction of prospective science teachers.

First, it may be used as a text for a broad general course in the fundamental principles of science teaching, intended for all those who are preparing for the teaching of any of the special sciences. In this case the chapters of general interest should receive the most study and attention; and those devoted to the special sciences, Chapters XII to XXIII, should be touched more lightly, being used for the most part as bases for special reports to the class by those most interested in the particular sciences of which these chapters treat.

Second, the book may be used as a text in a special course on the teaching of any one of the sciences. In this case the greater part of the book would be passed over rapidly to develop the general attitude and point of view; and the chapters on Biology or on Geography, Physics, Chemistry, or General Science would be studied intensively and supplemented by copious readings and reports based on references chosen from the book lists appended to the chapters so studied.

Third, in a university where special courses are given on the teaching of all of the several high school sciences this book may be used as a text in each one of these courses in the manner just described. In this case special joint conferences, attended by all these classes combined, may be arranged for. In these general meetings the leading principles brought out in the first eleven chapters and in the last may be made the subjects of general discussion by both instructors and students each from the viewpoint of the science in which he is most interested. By such a plan the courses of instruction in the teaching of all the sciences would be unified, and a common general viewpoint and a common philosophy of science teaching would gradually develop in the institution. This does not mean that such a unified viewpoint and such a com-

mon philosophy of science teaching would necessarily be reached only by adopting the views held by the author of this book, but rather that it would develop out of the discussions that a common study of the book must inevitably provoke.

Besides being employed as a text-book, it is believed that this volume will prove useful as a reference book in connection with more general courses in the principles of teaching or in methods of teaching; for the broader principles developed and formulated in it, and supported by arguments and examples, are those which science shares with all other subjects.

For high school science teachers in service, the book should be useful either for private reading and study or for study in groups such as teachers' meetings, reading circles, and science clubs, or as a text-book in extension or correspondence courses offered by colleges and universities for credit toward a degree.

For the supervisor who is not himself especially well trained in science the book should fill a long-felt want, for he often realizes that something in the science courses or in the way in which they are conducted is unsatisfactory, but does not know just what is wrong or how to go about correcting it. This book may serve to put such a supervisor in possession of principles that will enable him to diagnose the case, prescribe a remedy, and convince the science teacher that he should try the remedy and note the results. On the other hand, if some or all of his science teachers are doing particularly good teaching, a knowledge of the criteria for correctly judging their work will enable the administrator to appreciate its excellence and lead him to use all possible means of providing such equipment and administrative arrangements as are necessary for making it still more effective.

Although in referring to teachers the masculine form of the pronoun is used throughout, it should not be thought that the author wishes to ignore the noble body of science teachers who happen to be women. Let it be understood once for all that the book is addressed no less to women than to men,

and that what is said about teachers is meant to apply to teachers of both sexes.

For whatever there may be of truth or merit in these pages I am indebted largely to many persons. To my father, George H. Twiss, sometime teacher, meteorologist, and the founder and first manager of the Columbus telephone exchange, I owe a lasting debt of gratitude for the influences, brought about me during my boyhood, which first aroused and fed my interests in science. To my science teachers, especially the late Principal Albert N. Ozias, of St. Paul, Minnesota, who was my teacher in the sciences while a student in the old Columbus High School, and to Professors Thomas C. Mendenhall, Albert H. Tuttle, Sidney A. Norton, and the late Stillman W. Robinson, Nathan W. Lord, and Edward Orton, Senior, I am indebted for both my undergraduate training in science and much of what I may possess of skill in experimentation and insight into the scientific method. To them also, as well as to William Morris Davis of Harvard University and Charles Riborg Mann of the University of Chicago, I owe much for their inspiring methods of teaching, and the examples that I have observed through personal contact with them of clear-cut and attractive exposition of scientific facts and theories.

That the writings and teaching of Professors John Dewey and Edward L. Thorndike have had much influence in shaping the lines of thought that are developed in the following pages will be sufficiently evident to those who read them, yet it gives the writer special pleasure to acknowledge it here, and include them among those to whom the dedication of this book is addressed.

In putting the manuscript into final form, and in getting it through the press, I have profited by the criticism of a number of persons to whom my thanks are due, and are gratefully tendered; but I alone am responsible for any errors that may have evaded detection. Professor Paul Monroe

has read the entire work in manuscript and in proof; and Professor E. L. Thorndike has read the greater part of it in manuscript. Professors M. A. Bigelow, R. E. Dodge, and Alexander Smith, of Columbia University, W. W. Charters of the University of Illinois, and W. C. Curtis of the University of Missouri, have read those parts of the manuscript bearing on the subjects in which they are specialists. I am indebted to Professors John H. Woodhull of Columbia University and Fred D. Barber of Normal, Ill., for references and literature on introductory science. My wife, Blanche Olin Twiss, has helped me in the laborious work of verifying the references and book lists and revising the manuscript for the printers. Her criticisms and suggestions also have enabled me to improve the book at many points, both in clearness and in literary form.

Many authors whose books have been consulted in the preparation of this work have received credit in the footnotes; but there are others whose writings have helped indirectly in various ways to make the book what it is. They are too numerous to mention here, but many of them are mentioned in the text or included in the reference lists that are appended to the various chapters, or in the lists of books for high school libraries to be found in the appendix.

These book lists are not intended to be exhaustive bibliographies, nor are the prices appended guaranteed, but they have been selected with much care and labor; and it is thought that they include a sufficient quantity and variety of supplementary material to be of very considerable value, both for special references and general reading.

In the chapters treating of equipment, where prices are given, and where duty-free importations are mentioned, it is to be understood that reference is made to normal conditions, as they existed before August, 1914.

G. R. T.

July 17, 1917.

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