

# GENERAL INTRODUCTION

## Scope of the book

There is an on-going debate regarding the role of labwork in science education, which dates back several decades and which illustrates the conviction and interest of teachers, researchers and policy-makers world-wide in the value of laboratory work for understanding science. This is evident in more recent books and studies regarding the laboratory, which mainly refer to countries with a considerable tradition in practical work in science education (Woolnough & Alsop 1985, Hodson 1993, Hegarty-Hazel 1990, Wellington 2000). Yet in discussing research studies on labwork, several authors express their concern about its effectiveness in facilitating students' understanding of various aspects of scientific inquiry. They point out a comprehensive re-conceptualisation of the aims of labwork and, as a consequence, of investigating what the students actually learn in different contexts (Lazarowitz & Tamir 1994, Tobin & Tippins 1993, Lunetta 1998). It has also been argued that the relationship between instructional activities and student learning in labwork needs more attention than it has been given in science education research (Leach & Paulsen 1999). It appears that the case for research-based labwork emerges in several quarters in science education, particularly among researchers.

This book presents and discusses a variety of laboratory practices and their effectiveness. The studies take into account recent theoretical developments and empirical results concerning students' understanding of scientific inquiry. A whole chapter is devoted to technological advances offering new learning opportunities for the students and teaching facilities for the teacher. The authors set out to explore the potential of various ways of organising scientific experimentation, forms of data presentation and use of new information technologies for enhancing students' scientific understanding. In this respect, the book aims at making an up-to-date and substantial contribution to the discussion concerning on the one hand the differentiation of objectives and practices for labwork and on the other the effectiveness of labwork in promoting scientific understanding.

The book includes an edited collection of studies containing illustrations of teaching approaches and of students' learning acquisitions in the science teaching laboratory, presentation of new evaluation tools, theoretical frames and positions concerning laboratory work. One of the characteristic features of the book is that it focuses the discussion on the role of labwork in upper secondary and in higher education, whereas most research and discussion world-wide focuses on labwork in primary and lower secondary education. The target readers of the book are science education researchers, postgraduate students, science education teacher trainers and science education policy makers.

The studies are based on research and developmental work carried out in five European countries in the context of the European Project "Labwork in Science Education" (LSE), which was funded in the context of the Targeted Socio-economic Research Programme (TSER Programme) of the European Union (Séré, Tiberghien, Paulsen, Leach, Niedderer, Psillos & Vicentini 1998; Séré 2002). The project involved 35 researchers from seven European research groups from France, Great Britain, Germany, Greece, Italy and Denmark; the project was co-ordinated by M.G. Séré (University of Paris 11) and lasted for 28 months between 1996 - 1998. The project included surveys and case studies on labwork across the countries involved, producing several working papers, communications to conferences and publications in journals. The editors of this book co-ordinated the empirical case studies on labwork, which were undertaken as a major part of this project. A number of these case studies from the LSE project form the main body of this book. This research and developmental work from five European countries provides a unique framework for gaining deeper insights into the role of experimentation in science teaching and learning, in a variety of contexts. Certainly, not all important aspects of labwork are covered in these studies that are presented in this book. But one of its distinguishing features is the fact that it presents and empirically analyses laboratory practices in quite different countries and educational settings.

For example, on the one hand there is a study about field-work for geology undergraduates in Britain, a country with a long tradition in labwork. On the other there is a study about the introduction to data treatment for Greek physics undergraduate students with negligible previous laboratory experience. And a third study discusses upper secondary students' work with computer-based models in France. These examples show that the case studies reported in the book cover a wide range of situations spread across five European countries in both upper secondary and higher education.

Although the authors of the book adopt a variety of theoretical positions and methodological approaches, they have developed certain common perspectives and identified key issues concerning the teaching and learning of science in the laboratory. Such perspectives are illustrated in the case studies and are discussed in the theoretical Chapter 1 of *this book*. One shared assumption is that setting up a laboratory situation does not necessarily imply the desired learning by the students. Accordingly, the reported investigations carefully distinguish the various teaching contexts on the one hand and research designs aimed at monitoring students' learning on the other. This means that in each study there are descriptions according to various innovative frames, e.g. illustrations of the laboratory approaches and innovations on the one hand, and empirical results concerning students' learning acquisitions on the other, followed by policy recommendations. Such a distinction between teaching in the laboratory and research into learning reveals implicit assumptions and objectives regarding science learning and teaching which influence the organisation of several types of labwork.

The first important issue, which is extensively treated in the book, is the relation of conceptual knowledge to students' practical activities (White 1996). For a long time, both in published research and in actual teaching practice science educators have often been concerned as to whether and how students use or do not use

conceptual knowledge when performing experimental work. In this book, several studies make original contributions to this matter by setting up special teaching situations, focusing on students' scientific discussion (or lack of it) and actions during labwork. Several contributors search for ways to enhance the linking of the world of phenomena and procedures with the world of theory - an objective which gets high scores in science teachers' perceived priorities for labwork at both secondary and university education (Welzel, Haller, Bandiera, Hammelev, Koumaras, Niedderer, Paulsen, Robinault & von Aufschnaiter 1998).

The second important issue running through several studies in the book is the teaching and learning of scientific procedures, an issue, which is continuously debated by teachers, researchers and policy-makers. For example, measurements and data processing carried out by the students are investigated in a number of the case studies. Among the issues discussed is whether students meaningfully carry out measurements and how these are linked with the evaluation of scientific theories, which is an essential, yet not widely investigated, aspect of scientific inquiry. A number of case studies, for example, contribute substantially to the discussion on how labwork may encourage students to link theory with data.

A third issue, which emerges in the book, is the development of epistemological knowledge through labwork. In fact, this important dimension of scientific understanding has only recently started to be discussed between science educators in relation to labwork (Leach & Paulsen 1999). The authors of the various studies share the assumption that conceptual and procedural knowledge are intertwined (Séré 1999). They widen the scope of labwork, investigating and discussing its effectiveness with regard to conceptual, procedural and epistemological objectives. Often in the literature and in practice the discussion about the contribution of labwork to scientific understanding has been restricted to conceptual and procedural knowledge. How students' understanding of the nature of science influences their actions and learning during labwork is the focus of both theoretical positions and empirical investigations reported in various studies.

Too few attempts have been made so far to uncover the complex cognitive processes that take place during students' engagement in labwork: what happens and why as they carry out certain laboratory procedures. For example, one well-known observation taken up in the case studies is that students often fail to link manipulation of equipment with conceptual models or with the purpose of experimentation, often seeing labwork simply as a set of disconnected actions to be followed (Lunetta 1998). In this context, some of the case studies focus on students' cognitive constructions and models *before and after* labwork, investigating the matching between what students are intended to learn from the task and what they actually learn. Other studies focus on students' constructions *during* labwork and on the contextual factors determining what students actually do during experimentation, investigating the correlation between what students are intended to do in the task and what they actually do.

In effect, a new model of twofold effectiveness is suggested in the book, which distinguishes two main categories of labwork effectiveness leading to different sources of information in specific teaching contexts. In the first category, students' activities are related to those intended *during* labwork. In the second category,

students' achievements in relation to instructional objectives are studied *after* laboratory teaching (Psillos, Niedderer & Séré 1998; Psillos, Niedderer & Vicentini 1999; Millar, Le Maréchal & Tiberghien 1998, 1999). Illustrative examples of both types of effectiveness are provided in the various studies throughout the book. In addition, two theoretical contributions in Chapter 1 focus specifically on this matter, attempting to model students' activities during labwork in relation to the intended ones.

## Structure of the book

The book consists of an extended introduction, five main chapters (approaching labwork: frames and tools; standard labwork based on hands-on experiments; open-ended labwork; labwork based on secondary data; labwork based on an integrated use of new technologies), and an epilogue (towards targeted labwork).

In the introduction the two editors set out the frame and the rationale of the book and provide an overview of the various chapters.

In the first chapter of the book, four theoretical studies are included. They focus on general frames, methods and questions related to labwork and on the relation between theoretical models and experimental data from a disciplinary and learning perspective. New tools are explicitly presented for analysing laboratory tasks, for determining effectiveness, and for describing and evaluating students' activities during labwork. These tools are based on explicit hypotheses concerning the modelling of labwork and have been used in a number of empirical investigations.

The second chapter focuses on standard labwork during which students carry out hands-on experiments using standard laboratory apparatus and labguides. It may be noted that at the university level such labwork is common throughout Europe, particularly in introductory experimental courses. Some studies in this chapter investigate how students' actions and procedures as employed during experimentation are, or are not, intertwined with the theoretical knowledge which the experimental design draws upon in an attempt to shed light on the links between doing/thinking/learning during labwork. The studies focus on a variety of laboratory situations, which are set out specifically, indicating that a deep understanding of laboratory contexts/ learning interactions requires research on different levels concerning duration and task complexity. An interesting variation on standard labwork, which is presented in this chapter, comprises experimental teaching sequences or laboratory sessions based on an innovative representation and reconstruction of scientific knowledge and procedures that implies new links between the models to be taught and the corresponding experimental field. This chapter also includes a study on the presentation of experiments in ordinary textbooks, thus addressing a rather neglected, yet nonetheless important, relation between textbook and labwork, which can affect the image of scientific knowledge developed by the students, particularly in countries where labwork is not widespread.

The third chapter includes three studies focusing on open-ended labwork in which students are required to make some decisions for themselves as to how to act in various types of projects within a laboratory or in an open-field context. An important issue, which is discussed in this chapter, is what kind of scientific

procedures students are required to learn in addition to conceptual knowledge and whether their epistemological understanding may be effectively improved when engaged in investigative work such as field work. Another important issue is whether any epistemological information relating to the processes and strategies of scientific investigation should be explicitly presented to the students as advance organisers of their investigative work in different contexts. How students may be helped to make the transition from set practicals to open-ended investigative work, which involves understandings of scientific procedures, is another issue investigated in this chapter.

The two investigations presented in the fourth chapter are examples of a broad conception of labwork. Both studies focus on specific phases of labwork, which do not involve planning, manipulation of apparatus and data recording. These two case studies deal with students' introductory instruction in measurement and data treatment as well as the roles and functions of measurement in science. They focus on the relation between the concrete measurement process and abstract models of that process. These issues are studied in the context of handling secondary data or data of pre-laboratory teaching.

The fifth chapter involves five case studies, which explore the new possibilities for learning science provided by the use of computers and information technology, integrated into laboratory teaching in a variety of ways. New technology is used for data collection, for analysis and graphical representation of data, for model building with appropriate software, for simulation of a physical model as well as combinations of these types of uses. The situations illustrated and studied involve, for example, the manipulation of simulated microscopic entities, the use of the computer for data capture and model building, on line and off line. These are important innovations in labwork. Their effectiveness, however, has not yet been fully explored in science education, partly because of rapid changes in the technology used. In the context of this book, new types of laboratory activities, like engagement in computer-based modelling and in real time graphing, and their learning potentials, are discussed. Whether new skills are developed or whether the improvement in linking theory to practice can be brought about are open issues, which are treated in the various studies.

It is a shared assumption of the contributors that research-based labwork may be gradually developed out of specific policy recommendations linked to research outcomes. This is why in each empirical study specific recommendations are set out. Further on a major outcome of the Labwork in Science Education Project was the advancement of the concept of "targeted labwork". Targeted labwork for upper secondary and university teaching is extensively discussed in a separate theoretical study, which is included in the epilogue of the book.

## **Concluding remarks**

In concluding the presentation of the book, we expect that the widening of laboratory objectives, the illustrated examples of laboratory practices, the treatment of learning outcomes, the new tools, theoretical discussions and the policy suggestions will make interesting reading for a wide range of science educators. We expect the book to appeal to a wider public than researchers and postgraduate students; it could also supply valuable information to policy makers, teacher trainers