RESEARCH IN SCIENCE EDUCATION IN EUROPE

EDITED BY
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KLUWER ACADEMIC PUBLISHERS 1999

Case Studies on Innovative Types of Labwortk in Science Education

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Abstract

This paper outlines essential features of ongoing case studies carried out in the frame of the Laboratory in Science Education project. Although not all areas are covered, it is argued that these case studies allow a rich investigation in a variety of contexts of how aspects of understanding science can be facilitated by different types of labwork. Concerning laboratory effectiveness the case studies distinguish two main categories which lead to different sources of information in specific teaching contexts. In the first category students' activities are related to intended ones during labwork; in the second category students' achievements in relation to instructional objectives are studied after laboratory teaching.

Key words: laboratory work, case studies, laboratory effectiveness, types of laboratory work

Introduction

The Laboratory in Science Education project (LSE) set out to investigate practices and effectiveness of labwork in the light of recent theoretical developments and empirical results concerning students' understanding of science as well as technological advances offering new resources for teaching and learning opportunities for the students (Sere, 1997). As part of this project, 23 case studies are being carried out in six participating groups, in five European countries, focusing on how aspects of understanding science can be facilitated by different types of labwork .

Several studies have been carried out world-wide regarding the role and the value of laboratory work in understanding science. The debate shows, on the one hand, the conviction and interest of science educators in the value of labwork and, on the other hand, their concern over the effectiveness of laboratory work in facilitating students' understanding of several aspects of scientific inquiry. It has been argued that research results show an "appalling lack of effectiveness of laboratory instruction" despite the great promise of laboratory activities in enabling students to construct scientific

knowledge and to learn scientific procedures. It seems that the determination of the optimal kinds of laboratory experience for specific aspects of understanding science and the way these can be evaluated on the basis of research data comprise an issue requiring further extended and rich investigation. In this respect simultaneous work in the several and distinct LSE case studies provides a unique European frame for gaining deeper insights into the role of experimentation in science teaching and learning in a variety of contexts.

In LSE, the case study has been adopted as a multifaceted research methodology potentially capable of examining the influence of certain organisational and personal factors on labwork and of identifying, describing and modelling both students' achievements and their actions taking place when students are engaged in labwork. Adoption of the case study as a means of investigating the complexities of the interrelationships between engagement in labwork and understanding science implies that the labwork variables under study are linked to the context in which they are taking place (Merrian, 1988). Therefore, results from the LSE case studies are to be seen as important indications concerning the features and interrelations of complex contextual factors influencing the effectiveness of various laboratory types rather than leading to conclusions that can be easily generalised to other situations.

Changing perspectives and new foci of labwork

Earlier approaches to learning and teaching have conceptualised the contribution of labwork to scientific understanding in terms of an implicit or explicit focus on either the acquisition of knowledge or scientific skills. On the other hand, constructivist approaches to science teaching and learning, either individualistic or social, have prepared the ground for a different perspective on labwork raising the issue not only of knowledge construction but of the use that students make of their own or new scientific knowledge gained in labwork. In LSE case studies a shared assumption is that knowledge of the concepts and models of science and scientific procedures for coping with laboratory situations are intertwined and both are employed if the students are engaged in meaningful experimental activities (Séré, 1998). This implies new foci and meanings assigned to the research questions regarding the relationships between students' understanding of scientific concepts and practices and their engagement in labwork.

The role of experience in meaning making has been significant in constructivist approaches to teaching and learning science. However rather few attempts have been undertaken up to now to search for the complex cognitive processes taking place during students' engagement in labwork, what happens and why when they carry out certain laboratory procedures. For example, one well known open issue is that students often

fail to link manipulation of equipment with conceptual models or the purpose of experimentation often seeing labwork as a set of disconnected actions to be followed (Lunetta 1997). In this context several case studies focus on the one hand on students' cognitive constructions and models before and after labwork. On the other hand, a number of case studies focus on students' constructions during labwork and on the contextual factors determining what students actually do during experimentation. Concerning such a new research foci empirical results are expected from the case studies with regard to the potential contributions of labwork to students' understanding of both scientific concepts and procedures which may, for example, provoke them to become able to "see" scientific models behind reality, or to be able to link theoretical terms to apparatus or measurement.

Work on LSE is still in progress so, only a few results of the case studies are available at the time of writing this paper. Nevertheless, significant progress, has been made in understanding the features and potentialities of each case study. We developed a strategy for the progressive clarification and elaboration of the quantity and quality of the information required from the rich data the case studies seem to produce. As part of such a strategy, in collaboration with the various LSE groups, we developed a special report scheme in order to compile and code information from the various case studies. What is of interest here is that such a scheme helped researchers in revealing and clarifying, to a considerable extent, deeply rooted implicit assumptions underlying their piece of laboratory teaching and sharpening the foci of their research design.

Several positions underlined the development of such a scheme which were related to a consensus based view about the distinctive features of laboratory based case studies. One position was that it should facilitate the linking of particularistic elements of the case studies with broader issues on labwork. In other words, each case study should make explicit in what way and why their piece of labwork and research questions are worth investigation and reporting. A second position was that, concerning labwork carried out within LSE , the contextualised information needed should include researchers' views about:

a) Science;

b) learning Science in the laboratory and

c) teaching science in the laboratory.

A third position was that reports and corresponding case studies should carefully differentiate what often is undifferentiated in labwork i. e teaching context and research design regarding laboratory effectiveness. In the following section we present essential issues concerning the last position.

Teaching in the laboratory: innovative types

One essential feature of the case studies is their diversity concerning the focus of laboratory teaching. As a matter of fact, the LSE project has adopted a view, which broadens the range of labwork from the traditional hands-on small group work or class demonstrations of experiments in order to explore the potentialities of new technologies and types of organisation that focus on various types or phases of aspects of scientific experimentation (Millar et. al., 1997). The illustration of new types of activities and the evaluation of their effectiveness, independently or integrated in more traditional ones, are important foci of several case studies. For instance, in two German case studies microcomputer-based modelling systems are integrated in labwork in order to enhance students' capabilities to model data.

In LSE case studies, labwork may imply variously that: students may carry out the task themselves or watch a teacher carrying it out as in one Greek case study; students may obtain information not only from real objects and materials, but also from a video recording, a computer simulation, as practised in some French case studies; although it is recognised that students' activities are interrelated when they are involved in scientific investigation, labwork may focus on specific activities or phases of labwork which do not involve, for example, planning but only data treatment and drawing of conclusions from experimental results as in one British and one Greek case study; in other cases full instructions may not be given and instead the students are required to carry out open investigations. The later is the approach taken in a number of British and French case studies. Finally, information may be taken from a text-based account as in one Italian case study.

Research on laboratory effectiveness: multiple foci

The case studies accept that setting a laboratory situation does not necessarily imply the desired learning by the students and they carefully distinguish the various teaching contexts on the one hand and research designs aiming at monitoring students' learning on the other. The case studies accept that scientific understanding, as promoted by labwork, involves both students' learning of concepts and practices of science as well as their abilities to manipulate laboratory entities according to contextual demands. In effect, the effectiveness of laboratory teaching is distinguished into two categories called effectiveness 1 and 2 respectively; with regard to effectiveness 1 students' activities are related to intended ones during labwork; with regard to effectiveness 2 students' achievements in relation to the espoused instructional objectives are studied after laboratory teaching.

Research on activities during labwork: effectiveness 1

Several of the 23 case studies being carried out in the LSE project, e.g. French and German ones, are aiming at explicit modelling of students actions and cognitive processes during labwork. All these studies are obtaining data from ongoing activities during labwork, mainly by audio- or video-taping and transcribing afterwards which, often, are triangulated by paper and pencil assignments. The analysis of such data is strongly related to the theoretical background underlying one case study. The research aim is to illustrate relations between features of different kinds of intended labwork activities with the observed students' actions. For instance, students talking about relations between scientific concepts and real objects are considered as evidence of "relating theory and practice".

Two specific examples are the case studies presented in the Symposium "Case Studies about innovative types of Labwork in Science Education", held in the ESERA conference. In the first one, Buty (1997) analyses student activities during labwork while modelling real experiments in geometrical optics with computer modelling software. His main question is: What are the students' cognitive processes in modelling of physical situations during labwork, involving the use of a microcomputer? In the second, Niedderer et al. (1997) report preliminary results about students' explicit and implicit objectives in one German case study and hypothetical cognitive elements determining students' activities during labwork in another one .

Research on outcomes after labwork: effectiveness 2

This is the traditional way of analysing effects of laboratory teaching followed in a number of case studies e.g. Italian, British, French and Greek ones. Pre-post effects of labwork are studied in relation to the set instructional objectives following a whole teaching sequence involving labwork or single laboratory sessions. Research on learning outcomes aims at modelling students' achievements or evolution in a piece of labwork. This is attempted by pre-post-analysis of tests or other instruments such as concept maps, questionnaires or written reports. In several case studies interviews are widely used to obtain qualitative data before, in the middle and after instruction.

Two specific examples are the other two case studies presented in the same Symposium too. In the first, Evangelinos et. al (1997) used initial intermediate and final tests and interviews in order to investigate students' understanding and conceptual evolution concerning data treatment. In the second, Guillon (1997) used standard laboratory reports and special questionnaires in order to analyse students' understanding of physicists process. We may note that effectiveness 2 is not limited to achievements regarding the concepts and models of science but also include achievements regarding scientific procedures as in the case study by Guillon.

Work on the features of these two types of effectiveness and their relations is still in progress. However, one important remark is necessary. It may be noted that the two type of effectiveness are not considered as mutually exclusive. They rather give rise to different sources of valuable information concerning laboratory transactions. Thus, some case studies focus on both effectiveness 1 and effectiveness 2. For example, Niedderer et. al (1997) used conceptual inventories to evaluate students' conceptual understanding in mechanics.

Concluding remarks

Work on the case studies is still in progress at the time of writing this paper. We argue that one step towards gaining insights concerning labwork effectiveness is the exploration of both students' activities and constructions during labwork and their achievements after teaching. A careful distinction between teaching and research design is promising in revealing implicit assumptions including views about science, science learning and teaching, which are underlying several types of labwork.

Acknowledgements

This work has been funded by the General Directorate XII of the European Commission in Brussels. [Contract N° SOE2 CT952001] [1996-98].The issues raised in this paper are based on all case studies and have benefit in particular from the discussion between the group leaders of the project.

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