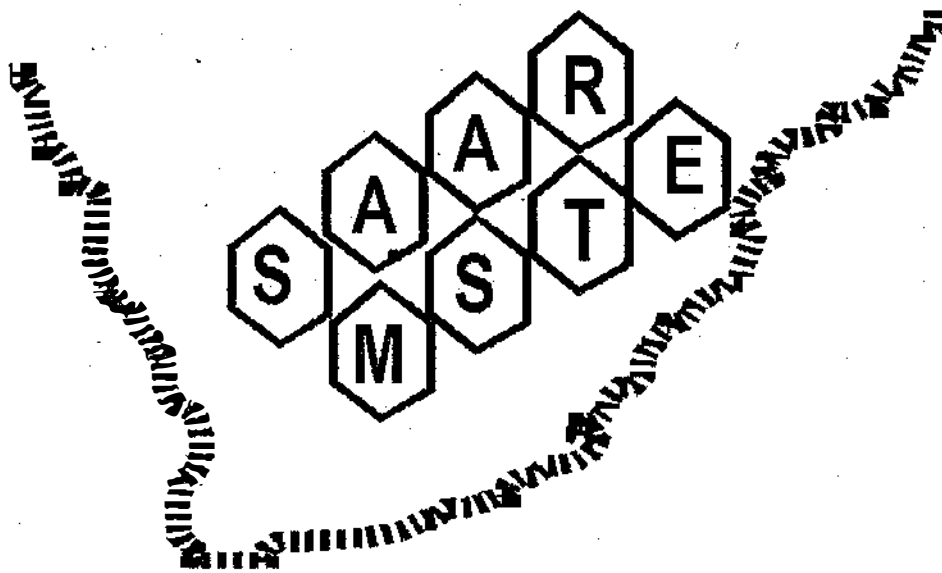


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The role of practical work in science teaching in Namibia

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Abstract

This paper presents a study into science practical work conducted in Namibian classrooms. Lesson plans, task sheets and student work are used to identify the intended learning outcomes. In addition, aspects of task design (inductive-deductive; open-closed; nature of student involvement) and the context of the practical task (duration; interaction patterns; types of task information and apparatus; nature of the student record) are explored. Millar's Profile Form is used to analyse twelve practical tasks. Findings show an emphasis on conceptual instead of procedural objectives, and a frequent change from an inductive to a deductive approach during the execution of the tasks. The practical activity is rarely consolidated in a laboratory report but functions as an enjoyable introduction to a set of unrelated consolidation questions. Suggestions are made for the modification of the analysis scheme, and for in-service activities to support teachers to use practical work more effectively.

1. Introduction

In recent years there has been an ongoing debate concerning the role of the scientific method in science teaching. The centre of most of such debates is the role of practical work. There is no great disagreement about the importance of practical work in school science. However, in both emerging and industrial societies the great concern is its objectives - what students are to learn from their experiences in laboratory work and its effectiveness in developing what it intends to obtain (Kahn 1990, Osborne 1996) A clarification of the learning benefits of practical work is particularly important for developing countries, as large sums are being allocated for lab facilities (Walberg 1991).

Millar, Le Marechal and Tiberghien (1999: 33) claim that "practical work with real objects and materials does not only help learners to communicate information and ideas about the natural world, but it also provides opportunities to develop students' understanding of the scientific approach to enquiry". However, most of the time practical work objectives are vague and ill-defined. Hodson (1990: 33) describes this notion very clearly as:

Practical work, as conducted in many schools, is ill-conceived, confused and unproductive. It provides little of real educational value. For many children, what goes on in the laboratory contributes little to their learning of science or to their learning about science. Nor does it engage them in doing science, in any meaningful sense.

Hodson (1993) describes practical work as often being dull and teacher-directed and highlights the point that students fail to relate their experiences to other aspects of their learning. In other words, practical work is most of the time purposeless, in the sense that the signal-noise ratio is too low (Johnstone 1997) and it may have too many teaching/learning objectives to focus on during instruction. For example, a teacher might use the same task to develop different competencies such as the skill of following instructions and of using objects and materials correctly. The focus when assessing objectives may then be divided and this in itself can minimise the effectiveness of practical work. Indeed, it may be very confusing to both teacher and students if they are not focusing on the same objective.

How then can practical work be arranged so that it is done by students in a meaningful way? Several classification schemes of practical work have been reported in the literature. For instance, according to Brown (1995), practical work involves:

1. exercises to develop specific skills;
2. investigations including hypothesis-testing or problem-solving;
3. experiments to introduce students to particular phenomena;
4. demonstrations to allow the teacher to develop a scientific argument or create a dramatic impression; and
5. fieldwork.

Millar, Le Marechal and Tiberghien (1999) include more aspects than only the type of practical activities in their classification scheme. They define practical work as: "those teaching and learning activities in science which involve students at some point in handling or observing real objects or materials they are studying" (p. 36). Their Profile Form (see Appendix) allows for differentiating the intended learning outcomes of a practical task. Secondly, it describes different aspects of the task design, i.e. what learners are to do with the physical objects and science ideas, how open or closed the task is, and the nature of the learners' involvement in the task. Thirdly, the context of the task is identified – its duration, the people with whom the learner interacts, the way instructions are provided, and the type of apparatus used. Lastly, the characteristics of the practical report are documented – its nature, purpose and audience.

Although research has been published about the desirable characteristics of practical work in developing countries (Kahn 1990, Swain, Monk and Johnson 1999), little is known about what practical activities teachers actually plan in African classrooms. This study documents practice in Namibian secondary science classrooms.

2. Science Education in Namibia

After gaining independence in 1990, Namibia underwent a reform in the education system. The Cape curriculum that prevailed in the country for more than three decades was replaced by the Cambridge-based International General Certificate of Secondary Education (IGCSE) curriculum system (MEC 1993). This change brought along several problems. Namely, most teachers were not trained for the new curriculum and its applications. Practical work and examination in practical work were absent in most school subjects. The government of Namibia has tried to introduce various upgrading

programs such as the Mathematics And Science Teachers Extension Project (MASTEP) for teachers at high schools. The IGCSE curriculum for each science subject is basically divided into three assessment domains:

Domain A: Knowledge with understanding

Domain B: Handling information and solving problems

Domain C: Experimental skills and investigations.

This study focuses on the use of practical work done in school science by under-qualified teachers undergoing training through the MASTEP project in Namibia in order to come up with possible recommendations and suggestions for this in-service programme. The study seeks to answer the following questions:

What is the range of intended objectives for practical activities included in the scheme of work or lesson plans in Namibian secondary schools?

What are the design features of the practical tasks used?

What is the context within which practical work is integrated in science lessons?

3. Method

Data on practical work were collected of 15 teachers in 6 schools, in town, peri-urban and rural areas. Teachers were asked to provide three forms of documentation of practical lessons they taught during the last half year - a lesson plan and, where available, worksheets and a sample of student work. In a few instances transcripts and classroom observation notes of the interactions during the practical lessons were available as additional data. Three of the authors independently used the Profile Form developed by Millar, Le Marechal and Tiberghien (1999) for analysing the data. Inter-researcher consistency was achieved for 72% of the codes during first round of coding. Discussion of discrepancies led to agreed clarification and refinement of the classification scheme. The analysis will highlight issues related to the use of practical work in Namibian classrooms. It does not claim to provide a representative overview of practice.

4. Findings

Sample of practical lessons

Three teachers (a fifth) failed to make any documents available as they claimed not to do practical work at all. The remaining 12 teachers submitted materials for a total of 13 practical lessons, 8 Biology and 5 Physical Science lessons, 5 at junior secondary and 8 at senior secondary level. The documentation for only three of these lessons was complete. The others usually missed a worksheet, with or without a sample of student work. The practical lessons included whole class and group demonstrations, large and small group hands-on work, a survey in the community, mini practical projects, a model making exercise and text marking. The last activity asked students to read through a description of an electrolysis experiment and (i) label the parts in the diagram and write what they do and (ii) mark in the text each step of the process of electrolysis. In line with the definition of practical work as a learning activity involving learners in handling and observing real object, the text marking described above was not considered to be practical work, thus leaving the analysis with twelve lessons.

Intended learning outcomes

The Profile Form (see Appendix) lists eleven possible learning outcomes, five conceptual and six procedural outcomes. Lesson plans mention mainly conceptual outcomes (to know the importance of diffusion, or to define the growth rate of a plant). However, student worksheets or consolidation questions often show intended procedural outcomes (Use your graph to calculate the diffusion rate. What is the evidence that a hormone at the tip causes the shoot to grow?). The few lessons for which additional transcripts are available show that teachers spontaneously teach procedural outcomes when the opportunity arises (when I increase the number of coils, what do you expect to happen to the deflection of the needle of the galvanometer?).

All but one practical lessons indicated that they are aimed at helping students to learn a fact or a concept (outcome b/c), e.g. movement of a magnet in a coil generates a current, or roots grow towards gravity. About half of the practical lessons aimed to familiarise students with objects or phenomena (outcome a), such as diffusion or littering. The same proportion of practical lessons intended to support students in learning a relationship (outcome d). This was usually a qualitative relationship - the direction of the light equates the direction of growth; the stronger the magnet moving in a coil, the larger the current induced. Hardly any lesson aimed at helping students to learn a theory or understand a model (outcome e).

Concerning the procedural outcomes, about two-thirds of the lessons aimed at helping students to use data to support conclusions (outcome j), e.g. use colour changes to identify different types of foods or the comparison of calculated density of water with the value in the databook. About half of the lessons intended to provide practice of a standard procedure (outcome g), e.g. the formation of salt crystals or food testing. Teachers clearly see this outcome as important, but some confusion exist. One teacher demonstrated diffusion by putting an ink droplet in a beaker with water, and then told groups to copy the procedure, apparently with the aim of making learners practice the technique instead of familiarising them with the phenomenon of diffusion. Seldom practicals aimed at helping students to set up or use a standard laboratory instrument (outcome f), to plan an investigation to address a given problem (outcome h) or to learn to process experimental data (outcome i). No lesson indicated that it specifically aimed at communicating the students' experimental results (outcome k).

Comparison with stated syllabus objectives

In the IGCSE Biology and Physical Science syllabi, the intended conceptual outcomes are summarised in Domain A, *Knowledge with understanding*, such as *to demonstrate knowledge and understanding in relation to scientific phenomena, facts, laws, definitions, concepts and theories*. These correspond with the Profile Form's conceptual outcomes a-e. According to the IGCSE syllabi, the intended outcomes of Domain C, *Experimental skills and Investigations* require the students to:

Use techniques, apparatus, and materials (including the following of a sequence of instructions where appropriate);

Make and record observations and measurements;

Interpret and evaluate experimental observations and data;

Plan and carry out investigations, evaluate methods and suggest possible improvements (including the selection of techniques, apparatus and materials).

From the Profile Form, the intended procedural learning outcomes (f-j) are clearly described in the IGCSE syllabi. It is significant that outcome (k) 'to help students learn how to communicate the results of their work' is not highlighted in the syllabi.

Design features of the task

The Profile Form separates the design features of the task in two main categories. First, the scheme shows 11 options (B1.1a-k) of 'what students are supposed to do with the objects'. In the 12 lessons these options are equally represented except *that the observation of an event* (B1.1j) is present in the vast majority of the tasks. Secondly, the scheme shows 13 options (B1.2a-m) of 'what students are intended to do with the ideas'. About half of the tasks require students to *report observations* (B1.2a) and *account for observations in terms of a given explanation* (B1.2k). Several tasks require students to identify patterns (B1.2b), explore relationships between objects (B1.2d), or test a prediction from a guess (B1.2h). Other options hardly feature: students were not asked to 'invent' a new concept (B1.2f), test predictions from a law or theory (B1.2i/j), or account for observations by choosing between two rival hypotheses or by proposing an explanation themselves (B1.2l/m).

The scheme differentiates between objects-driven tasks, i.e. supporting inductive learning from 'discovered' results, and ideas-driven tasks, i.e. supporting more deductive learning confirming science concepts and laws. For the practical tasks in Namibian classrooms this distinction does not seem helpful, as most tasks start off asking learners to manipulate the objects and observe phenomena or collect measurements, indicating an object-driven discovery learning approach. However, when it comes to the stage of processing and interpreting the data the task turns into an ideas-driven one. Learners are asked to recognise firstly a specific pattern in the data they have collected, and then project this on the accepted science concept, theory, or model both provided by the teacher.

The IGCSE Biology and Physical Science syllabi don't give a clear indication of what learners are intended to do with objects and ideas, that is, whether tasks should be objects- or ideas-driven. When considering what students are intended to do with objects, the syllabi focus on only two aspects of the Profile Form, i.e. use and observe, but not on presenting or displaying, nor on making objects or materials. However, the syllabi list other outcomes such as make and record measurements. Equally, outcomes such as estimate, interpret and evaluate experimental observations and data are not found in the Profile Form. The IGCSE syllabi clearly state what students are required to do with ideas in Domain B (Handling information and problem solving) but not in Domain C (Experimental skills and investigations) which deals with practical work. This feature might be confusing for teachers when planning practical lessons.

The data show that, in general, the practical tasks are closed in nature. For all practical tasks the teacher prescribes the question to be addressed, the equipment to be used, the procedure to be followed and (mostly) the methods of handling the data. Even if data handling methods are not prescribed from the start (by asking learners to fill in a given

table), plenary sharing of data and establishing consensus on the results for the whole class converges in an agreed data handling method. The construction of teacher-led consensus is even more common for the interpretation of results. Invariably the interpretation of the lab work leads to teacher-sanctioned notes used for revision.

The existing classification scheme does not provide fully for the ways Namibian learners are involved in practical work. Small group work and plenary demonstrations rarely occur. A third of the tasks in this study were teacher demonstrated to a number of large groups observing in turn. No learners were asked to support the demonstration. These groups (8-12 learners each) were then instructed to continue working together. Mini-project, for instance on tropism, and even tasks aimed at practising laboratory procedures were also conducted in such large groups. This represented half of the tasks. Only a few tasks were aimed at individual learners.

Practical context of the task

The duration of the tasks generally covers a whole lesson or a double period (40-80 minutes), specifically set aside for practical work. As mentioned earlier, in half of these cases individual students observed a much shorter demonstration in their group. They devote the remainder of the period discussing the data and possible conclusions and answering some consolidation questions. A plenary discussion of the experiment will complete the period. Learners were involved in the mini-projects for parts of 3-5 science lessons. Only rarely was practical work included as a (short) learning activity in a 'theoretical' science lesson.

The interaction pattern in practical science lessons is common for all tasks. Learners interact with peers within their large workgroups, and during the plenary discussions. The latter also invariably gives interaction with the teacher. Demonstrators and technicians are not part of the Namibian school environment. Thus, the item on learner interaction does not differentiate for any of the tasks. The way task information was provided was not always clear from the lesson plan or the student work. In a few cases instructions are issued only orally, or learners are referred to a textbook. However, in the majority of cases written information was given, either as a hand-written worksheet, or, more frequently, as instructions on the board. In half of these cases there is evidence that teachers also elaborated the same instructions orally.

The types of apparatus (and materials) used during practical work are of interest. No interface to computers was used, and the capacity for this learning aid does hardly exist in Namibian schools. Three quarters of the tasks involved standard laboratory equipment and materials, and half of the tasks required everyday equipment or materials. The apparatus in the latter group was equally split between equipment/materials which fulfilled its everyday function (foodstuffs for food tests, and plastic bags for collecting litter), and those which constituted improvised laboratory equipment/materials, such as cardboard boxes and table dishes to grow cresta seeds in. Such improvised apparatus deserves a category *per se* amongst the classification of types of apparatus involved.

Student record of work

It is very surprising that for more than half of the practical tasks no record of the procedures, data or conclusions of the practical work is available. Lesson plans do not indicate that teachers intended learners to produce such records. Seemingly the intention of practical work in these cases is the provision of a memorable experience. For half of these (unrecorded) tasks, the practical experiences provide the starting point for answering a number of consolidation questions. These are often only remotely related to the experimental procedure followed or to the specific data collected. For a quarter of the tasks, learners filled out a worksheet. In one case each they were asked to use the data to plot a graph (for the diffusion rate) or to make a calculation (for a density). If a record was kept, this was invariably to assist learners in revision for examinations, and a quarter allowed assessment of learners' performance.

5. Discussion and conclusions

Appropriateness of the analysis scheme for practical work in Namibian classes

Although a larger study is required to provide a representative overview of what takes place in practical activities in Namibian science classes, this study validly tests the usefulness of the Profile Form to describe these activities. The data show that, on the whole, the scheme is suitable to map practical work in Namibian classrooms. There are, however, some areas which need adjustments. The options for the nature of student involvement (B1.5) and for the duration of the task (B2.1) need to be expanded in order to include the practice of teacher demonstrations to large sequential groups of students rather than plenary demonstrations. Equally, the options for the type of apparatus used (B2.4) needs to be expanded to include improvised equipment (i.e. replacement of standard laboratory apparatus), as different from everyday equipment used for everyday purposes.

The lesson plans *per se* appear to provide only a limited picture of what actually goes on in classes during practical lessons, both in intended learning outcomes, design features of the tasks, the context of the tasks and the student records of work. Student work and particularly lesson transcripts show that, once interacting with learners, a much larger range of learning objectives and teaching strategies are used by teachers than shown in their lesson plans. Seemingly, an analysis based on lesson plans only, underrates teachers' professional depth.

Intended objectives of the practical activities:

The data show that teachers indicated mainly conceptual objectives in their lesson plans such as learning a fact or a concept, familiarisation with objects or phenomena, or learning a relationship. Considerably less stress was laid on learning a theory/model. A recent study of labwork tasks used in secondary schools in six European countries (Tiberghien, in press) shows the same pattern. Few, but not enough, procedural objectives are implicitly included in Namibian consolidation questions, most frequently using data to support a conclusion, or the practice of a standard procedure. Rarely teachers used practical work to develop skills in planning an investigation, in processing experimental data, or in communicating results of experimental work. The low priority of the latter is not surprising, as this objective does not feature in the Namibian syllabus. In the

European study the same priorities emerged. It is suggested that Namibian teachers should be trained to include the full range of procedural objectives such as planning investigations, setting up standard equipment and processing data. In-service programmes such as MASTEP may be used as a platform for distributing tested practical worksheets and consolidation questions, stating clearly the objectives for each.

The conceptual outcomes (a-c) are not part of the Domain C while the intended procedural learning outcomes (f-k) are clearly described in the IGCSE Biology and Physical Science syllabi. This may indicate that the curriculum designers support the view that conceptual outcomes may well be achieved through methods other than practical work. Recent work with schools in South Africa shows that even several of the procedural outcomes, e.g. learning to process data and using data to support a conclusion, may be achieved by paper-based 'translation' tasks (Johnson, Monk and Hodges 2000).

The design features of practical tasks

Namibian practice allows for the identification of what students are expected to do with objects and with ideas. Classifying tasks as object-driven, i.e. using an inductive approach, or as ideas-driven, i.e. using a broadly deductive approach, is more difficult. Lesson objectives are often phrased in a deductive way, i.e. to prove a law. However, full lesson plans and particularly transcripts show that several practical activities use an inductive method at the start, but frequently switch to a deductive method halfway through the activity. This switch is only possible due to the close guidance provided by the teacher during the activity. The ambivalence in the use of the two major paradigms in practical work may indicate the conflict between the officially propagated learner-centred approach for the start of the activity, and the traditional authority-based approach more akin to the teacher's own learning experience for the completion of the activity.

The practice of 'sequenced group demonstrations' is used in order to deal with large classes and lack of equipment. Its management needs to be improved. Instead of one activity demonstrated to each group in turn, students in smaller groups could be asked to do different activities and then the groups should rotate to complete all the arranged practical work. Thus, teachers should be encouraged to set up different activity centers for learners and learners should also be given different problems to investigate.

The context of practical work in science lessons

It is striking that for the majority of the practical activities minimal written information is provided, and hardly any written reporting is required. This may well be related to the time requirements of lab reports or of filling in worksheets, particularly with ESL learners. However, teachers need to be helped to ensure that all necessary information for practicals is written down to avoid disrupting the flow of practical activities by constantly reminding students of what is to be done. Also, teachers may develop tasks where the science activity report reinforces the appropriate use of English, supporting learning in both subjects.

A fifth of the teachers in the sample do not provide practical work at all. The remainder only offers few opportunities for student practical work. Practical lessons are currently

set aside but they do not represent 'full practical lessons', that is, where learners are expected to have hands on experience. Also, several practical activities only provide an (enjoyable?) introduction to answering worksheet questions which are unrelated to the practical activity other than that they deal with the same science concepts. In many cases, recording observations or measurements are seen as peripheral, and thus drawing conclusions or making generalisations from experimental results are done orally and plenary, if at all. The reason for this remains unclear from this study. But one may hazard a guess, that this is probably due to lack of laboratory facilities, materials, equipment and appropriately qualified teachers (MBEC 1996).

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Appendix 1 Practical work task: Profile Form
(from Millar et al., 1999)

A Intended learning outcome (learning objective)

a	to help students identify objects and phenomena and become familiar with them
b	to help students learn a fact (or facts)
c	to help students learn a concept
d	to help students learn a relationship
e	to help students learn a theory/model
f	to help students learn how to use a standard laboratory instrument, or to set up and use a standard piece of apparatus
g	to help students learn how to carry out a standard procedure
h	to help students learn how to plan an investigation to address a specific question or problem
i	to help student learn how to process data
j	to help students learn how to use data to support a conclusion
k	to help students learn how to communicate the results of their work

B1.1 What students are intended to do with objects and observables

Use	an observation or measuring instrument	a
	a laboratory device or arrangement	b
	a laboratory procedure	c
present or display	an object	d
Make	an object	e
	a material	f
	an event occur	g
Observe	an object	h
	a material	i
	an event	j
	a quantity	k

B1.2 What students are intended to do with ideas

report observation(s)		a
identify a pattern		b
explore relation between	Objects	c
	physical quantities (variables)	d
	objects and physical quantities	e
invent' (or 'discover') a new concept (physical quantity, or entity)		f
determine the value of a quantity which is not measured directly		g
test a prediction	from a guess	h
	from a law	i
	from a theory (or model based on a theoretical framework)	j
	in terms of a given explanation	k
account for observations	by choosing between two (or more) given explanations	l
	by proposing an explanation	m

B1.3 Objects- or Ideas-driven?

- | | |
|---|---------------------------------------------------------------------------------------------------------|
| a | What the students are intended to do with ideas arises from what they are intended to do with objects |
| b | What the students are intended to do with objects arises from what they are intended to do with ideas |
| c | There is no clear relationship between what the students are intended to do with objects and with ideas |