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THE IMPACT OF MASTEP ON THE USE OF PRACTICAL WORK IN NAMIBIAN SCIENCE CLASSES

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Abstract
This article presents an investigation into the changes in the teaching practices of practical work in senior science classes in Namibia. The teachers in this study are involved in a training programme, the Mathematics and Science Teacher Extension Programme (MASTEP). Pre- and post-intervention data were collected from eight Biology teachers and four Physical Science teachers. Lesson plans, worksheets and other documentation were used to characterise practical activities using an established taxonomy. Classroom interactions were audio-taped and transcribed verbatim. The findings indicate an increased focus on practical activities aimed more at qualitative rather than quantitative understanding of science concepts. In addition, the Post-MASTEP teachers favoured small group work and demonstrations. The changes in teaching practices are attributed to the improved PCK that has enabled teachers to align their practice with the assessment system.

Introduction

The paper presents a study of how secondary school science teachers use practical work in senior science classes in Namibian secondary schools. The study focuses on a group of teachers on a two-year, in-service training programme (MASTEP). It also describes some aspects of the use of practical activities by science teachers before and after following the in-service training programme.

MASTEP (Mathematics and Science and Teacher Extension Programme) originated as a professional development course that uses distance education, residential workshops and school placements. It aims to upgrade science and mathematics teachers trained for lower secondary schooling to enable them to teach effectively at senior secondary (IGCSE) level. The intended outcomes of MASTEP emphasise a change in teachers' classroom behaviour, rather than merely a change in their knowledge, skills or attitudes. The underpinning philosophy focuses on strengthening teachers' pedagogic content knowledge (PCK) as the "special amalgam of content and pedagogy that is uniquely the providence of teachers" (Shulman, 1987 p.3).

Thus, the programme draws on the PCK of successful current classroom practitioners as tutors (also see Van Driel *et al.*, 1998), rather than on experts in subject content or in educational theory. Customised interactive distance education materials for developing PCK make teachers reflect on their own experiences (Zembal-Saul *et al.*, 2002). Also a major component of the programme is the portfolio assessed classroom placement by close interaction between trainee and an exemplary host teacher trained as a mentor (Wolf, 2003). As a prerequisite for strengthening teachers' PCK as a way of changing their classroom behaviour, a robust subject knowledge is required, especially the subject knowledge at school level. Thus, MASTEP uses advanced level student distance education materials for strengthening teachers' subject knowledge rather than especially written or undergraduate materials for teachers. The programme's assessment package includes a written test equivalent to school-leaving IGCSE examination. Residential sessions focus on hands-on content activities including practical work, many immediately usable in class. Accompanying how-to-teach tips provide the bridge with the evolving PCK.

Practical work has long been a feature of school science education but the role and intended learning outcomes of practical work have been the subject of considerable debate (see for example, Bekalo & Welford, 2000; Hodson & Bencze, 1998; Millar *et al.*, 2002). With regard to practical work, it is difficult for a teacher to plan systematically without having a clear understanding of the aims of the practical tasks being set. If learners are to cope with the demands of such tasks they must possess appropriate conceptual and procedural understandings with regard to practical work (Psillos & Niedderer, 2002). In short, teachers need to be able to select practical activities that match intended learning outcomes. Such learning outcomes extend beyond substantive facts and concepts to gaining an understanding of how to collect evidence from practical activities and how to analyse, validate and use this as a basis for decision-making (Roberts and Gott, 1999).

Teachers can unknowingly create significant difficulties for their students by judging incorrectly what their students are and are not capable of doing (Leach & Scott, 1995). Good teachers overcome this by appropriate use of their PCK. The task of in-service programmes of influencing established practices of practical work is very challenging, as illustrated by Maboyi and Dekkers (2003) who reported that teachers' views of practical work remained very similar before and after completing an Advanced Certificate course in science education with a strong emphasis on practical work.

The MASTEP approach to supporting teachers in developing appropriate uses of practical activities is through enhancing their PCK. In doing so, the programme integrates content and pedagogy, theory and practice. It builds on teachers' own knowledge and experience of practical work and alerts them to a wide range of purposes and forms of practical activities. Stress is given to the notion that practical activities ask learners to deal with objects and observable things, or with ideas. A strong message to teachers that runs through the materials is the need to use practical experiences for learners, not just to help them to understand the subject content but also help them to develop the experimental and procedural abilities as both are assessed in the IGCSE examination. For example, after studying one particular module MASTEP teachers are expected to be able to:

- State key purposes of practical activities;
- Categorise different forms of practical activities;
- Identify the important learning outcomes of different types of practical activities;
- Give examples of the difficulties faced by learners in doing practical activities and how these may be minimised;
- Explain the limitations of practical activities as an aid to learning;
- Link practical activities with the requirements of the IGCSE examination syllabus.

The main goal of MASTEP is to impact positively on classroom practice. This paper thus deals with change in the use of practical work and addresses the following questions:

1. How does the range of MASTEP teachers' intended objectives for practical work in science lessons change after completing the programme?

2. How does the way in which MASTEP teachers manage practical work in science lessons change after completing the programme?

Methodology

Classroom data on practical work were collected at two points in time from the same group of twelve MASTEP teachers, eight teaching Biological Science and four teaching Physical Science. The first set of data was collected from teachers newly enrolled in the programme while the second data set was collected towards the end of their two years of study. At each point two forms of data were requested:

- a collection of documentation on three recent lessons that included or were devoted to practical activities;
- notes on observed lessons.

The request for documentation asked teachers to supply copies of materials such as lesson plans, worksheets, assessment materials, visual aids and learners' writing and references to texts, syllabus sections and other resources. Altogether, material was collected for eighteen biology and eight physical science pre-intervention practical tasks, and for nineteen biology and ten physical science post-intervention tasks. Classroom observations were conducted by a non-participant observer who recorded classroom interactions by using an audio tape recorder placed at the front of the classroom. The observer used a pre-tested observation form to note teacher and learner behaviours, classroom management strategies and the use of resources and materials. Such observations supplemented the documentation. The audio tape recordings were transcribed verbatim and along with the lesson observations were used to supplement documents to help characterise lessons.

The taxonomy developed by Millar *et al.* (1999) for school laboratory work has been used as a starting point for the characterisation of practical work. A previous study (Kapenda *et al.*, 2002) has shown that this is appropriate for the Namibian context.

Two or more of the authors coded practical activities independently. For those cases where consistency of coding was not achieved discussions of discrepancies led to a quick agreement. Frequency counts of activity characteristics were used to inform analysis of practices of MASTEP teachers prior to and following the INSET programme. This analysis highlights issues with relevance beyond the Namibian context of the study, in particular, in relation to professional development programmes based on a PCK approach.

Findings

Intended objectives of practical activities

Rather than analysing practical activities by topic, the teaching objectives were identified for each. The eleven objectives used by Millar et al. (1999) were grouped in six clusters, two in the conceptual and four in the procedural domain. These clusters of objectives are defined as to help students to learn:

- science facts, concepts or phenomena;
- science relationships, theories or models;
  how to use a laboratory instrument or standard procedure;
- how to plan an investigation;
- how to process data or to use data to support a conclusion;
- how to communicate the results.

The data did not include any activities with objectives in the last three clusters. Using data for drawing conclusions was required for many of the activities but was not highlighted as a specific teaching objective. Similarly, many activities involved making a record of the observations but this was not the specific teaching objective. Thus all tasks, classified according to their specifically stated teaching objectives fell within the first three clusters above.

The frequencies of the objectives of all practical activities are shown in Table 1. Qualitative and quantitative activities for the first two clusters (covering the cognitive domain) have been separated.

Table 1. Specified teaching objectives of practical activities (n=52, mutually exclusive)

Category	Intended teaching objectives of activities	Frequencies (%)		
		Pre-MASTEP (n=23)	Post-MASTEP (n=29)	Total (n=52)
A	To help students learn facts, concepts, phenomena (qualitative)	2 (9)	11 (38)	13 (25)
B	To help students learn facts, concepts, phenomena (quantitative)	3 (13)	2 (7)	5 (10)
C	To help students learn relationships, theory/models (qualitative)	2 (9)	5 (17)	7 (13)
D	To help students learn relationships, theory/models (quantitative)	5 (22)	1 (3)	6 (12)
E	To help students learn how to use a laboratory instrument or standard procedure	11 (48)	10 (35)	21 (40)

Table 1 shows that 35% of the practical activities focus on improving learning of facts, concepts or phenomena, 25% focus on relationships, theories or models and 40% aim at laboratory procedures. It also shows that some changes occur over the intervention period. The proportion of activities focusing on helping students to learn facts, concepts or phenomena (categories A+B) doubled from 22% to 45%. The proportion of activities aiming to help students to learn relationships between variables or understanding of models or theories of knowledge (categories C+D) has decreased slightly from 31% before to 20% after MASTEP. Similarly, the proportion of activities helping students to develop standard laboratory procedures (category E) has decreased from almost one in two of the practical activities to one in three (from 48% to 35%). The proportion of qualitative activities (categories A+C) has increased considerably from one in six to more than one in two, and the proportion of quantitative activities (categories B+D) has decreased from one in three to one in ten. These trends apply equally to activities aimed at learning concepts and those aimed at learning relationships.

Managing practical activities

The four categories used by Millar *et al.* (1999) for the nature of student involvement were extended with an additional three categories (C-E) in order to cater for the practices in Namibian classrooms. The usual size of small groups (F) would vary from three to five students, and large groups (E) from eight to fifteen students. The information in Table 2 below is arranged according to an increasing student control over what happens during practical activities.

Table 2. Nature of student involvement in practical activities (n=52, not mutually exclusive)

		Frequency (%)	
Category	**Nature of student involvement**	**Pre-MASTEP (n=23)**	**Post MASTEP (n=29)**
A	Demonstrated to whole class by teacher: students observe	1 (4)	4 (14)
B	Demonstrated to whole class by teacher: students observe/assist as directed	4 (17)	8 (28)
C	Demonstrated sequentially to student groups by teacher: students observe	-	1 (3)
D	Demonstrated to whole class by student(s) supported by teacher	2 (9)	-
E	Carried out by students in large groups	6 (26)	1 (3)
F	Carried out by students in small groups	10 (43)	15 (52)
G	Carried out by individual students	2 (9)	3 (10)
U	Unknown		1 (3)

Table 2 shows that both before and after the MASTEP interventions, the largest proportion of practical activities was undertaken in small groups (F), and that a sizeable proportion of practical work is demonstration (A-D). There is little individual work (G). Table 2 also shows that over the intervention, practical activities carried out in large groups have virtually disappeared in favour of small group work and demonstrations. In fact, the proportion of demonstrations has increased from 30% before MASTEP to 45% after the intervention. Some of these demonstrations (one pre-MASTEP and four post-MASTEP tasks) were followed immediately by small group work.

Woolnough and Allsop (1985) have shown the learning of facts, concepts, phenomena, relationships and theories (*i.e.* the conceptual knowledge of science) can be aided by practical demonstrations. Therefore, the intended learning outcomes of practical demonstration before and after MASTEP have been analysed and are presented in Table 3 below.

Table 3. Objectives of practical demonstrations (n=15, mutually exclusive)

		Frequency	
Category	**Objectives of practical demonstration**	**Pre-MASTEP (n=6)**	**Post MASTEP (n=9)**
A	Conceptual understanding: helping students to learn facts, concepts, phenomena, relationships, theories	5 (83)	3 (33)
B	Procedural understanding: helping students to learn how to use a laboratory instrument or standard procedure	1 (17)	6 (67)

Although the numbers are small, the trend is convincing. A large proportion of practical demonstrations undertaken before the intervention focussed on developing conceptual understanding whereas after MASTEP, a large proportion focussed on developing procedural understanding.

Information provided to students on practical activities

Table 4 below shows the way in which information was provided to students. In the majority of cases both pre- (70%) and post- (85%) MASTEP, teachers provided written information in the form of a worksheet. In half of these cases the worksheet information was accompanied by oral instruction to elaborate or explain what was on the worksheet. In most cases no additional information was provided. Teachers also used textbooks, wrote information on the chalkboard or overhead projector and referred to posters.

Table 4. Ways in which information was provided to students (n=52, mutually exclusive)

Form of Information	Frequency (%)	
	Pre- MASTEP (n=23)	Post- MASTEP (n=29)
Worksheets	8 (35)	13 (45)
Worksheet & oral instruction	8 (35)	11 (38)
Other	7 (30)	5 (17)

In the majority of cases both pre- (70%) and post- (83%) MASTEP, teachers provided written information in the form of a worksheet. I half of these cases the worksheet information was accompanied by oral instraction to elaborate or explain what was on the worksheet. In most cases no additional information was provided. Teachers also used textbooks, wrote information on the chalkboard or overhead projector and referred to posters. No substantial changes took place in this respect due to MASTEP.

Equipment and materials used in practical activities

Practical activities were analysed for the type of apparatus and materials involved, and these classified as standard laboratory, improvised, everyday or specialised models. For this paper we have classified equipment *replacing* standard laboratory equipment as *improvised* (*e.g.* kitchenware and drink containers). Where everyday materials were used as the focus of study they were classified as *everyday* (*e.g.* foodstuffs)). A summary of the frequencies is provided in Table 5 below.

Table 5. Types of equipment/materials used in practical activities (n=52, not mutually exclusive)

		Frequency (%)	
Category	**Type of Equipment/materials**	**Pre (n=23)**	**Post (n=29)**
A	Standard laboratory equipment/materials	21 (91)	24 (83)
B	Improvised laboratory equipment/materials	1 (4)	6 (21)
C	Everyday equipment/materials	12 (52)	15 (52)
D	Model	-	3 (10)

Table 5 shows that the large majority of practical activities pre- and post-MASTEP involve *standard* laboratory equipment. More than half of all activities, both pre- and post-MASTEP, involve *everyday* equipment/materials. The percentage of practical activities using

improvised equipment is small. However, there is a considerable increase from pre- to post-MASTEP. Examples of the use of improvised equipment are the use of kitchen knives for scalpels, washing-up bowls for glass troughs and cut-off plastic bottles for beakers. Some emphasis on model making has emerged after MASTEP, with models provided by the MASTEP course itself (making a 3-D heart, modelling the circulatory system) being used in class.

Discussion

While we need to keep in mind that the findings from our small group of teachers may not reflect the practices of all the programme graduates, they do evidence changes in the ways in which these teachers approach practical work and so offer encouragement to INSET providers. However, the study focused on intended learning outcomes as evidenced in lesson plans, worksheets and textbook references. Van den Akker and Verloop (1994) claim rightly that the implemented curriculum may deviate from the planned curriculum. Far from indicating a curriculum experience removed from that planned, classroom observations in our study point to a refinement and amplification of intended learning outcomes rather than their replacement.

Intended objectives of practical activities

What is striking in the findings is that the learning outcomes of practical work show a shift from quantitative outcomes pre-MASTEP to qualitative outcomes post-MASTEP. This would suggest that teachers may have come to see it as important to encourage learning of the key points about phenomena, sets of facts or essential concepts rather than possibly obscuring these by seeking to make measurements that might blur the important learning outcomes. MASTEP aimed to help teachers secure their knowledge and understanding of IGCSE science and to enhance their PCK. It can be argued that if this has been successful then teachers are better able to first establish the 'big picture' before developing the fine grain detail.

The findings also show a shift from practical activities directed to learning about relationships and theories and on how to use a standard laboratory procedure towards tasks focussed on learning facts, concepts and phenomena. While the IGCSE syllabus requires all these to be covered this shift may well reflect an appreciation that the IGCSE examination focuses more on the former than the latter. Indeed, the teachers studied have emphasised a limited set of teaching objectives. This is equally true of lessons before and after MASTEP. Although the same appears in other studies (Millar *et al.*, 2002; Kapenda *et al.*, 2002) this narrow range is disappointing. Three categories of procedural objectives for practical work listed in the taxonomy of Millar *et al.*, (1999) (how to plan an investigation; how to process data or to use data to support a conclusion and; how to communicate the results) do not feature. The first two of these objectives are included in the IGCSE syllabus but are not examined directly. Such observations may indicate that the focus on PCK has resulted in assessment driven rather than curriculum driven practice.

Managing practical activities

Schools in Namibia are no different from those in many other parts of Southern Africa and are characterised by large classes. The practice of MASTEP teachers seems to have moved during the intervention, so that practical activities carried out in large groups have virtually disappeared in favour of small group work and demonstrations. This may well reflect teachers' experience and learning of the pedagogic advantages of different practices and of skills for their organisation and management.

The lack of specialised resources is a well-documented reason for not doing practical work. The MASTEP distance learning materials suggest alternatives to purchasing expensive laboratory apparatus and materials and use such in workshops. It is thus encouraging to record a more frequent use of improvised equipment in the post-MASTEP data. While small group work remained the

dominant arrangement for doing practical activities the proportion of demonstrations increased. Although post-MASTEP demonstrations still aim to help students gain conceptual understanding a greater proportion aim to help them learn how to use laboratory instruments and procedures. One possible explanation for the practice of post-MASTEP teachers is the appreciation of the importance of students knowing how to perform certain laboratory procedures as prescribed in the IGCSE syllabus but the realisation that their practical abilities will be tested only indirectly through a written examination. They thus deal with such learning as if it was conceptual rather than procedural.

The vast majority of practical activities are supported by a worksheet. Such worksheets are most often generated in school but there is some evidence that materials used at MASTEP workshops are also being utilised. The number of practical activities with accompanying worksheets increases slightly in the post-MASTEP lessons. What is particularly noticeable is that in just over a third of the situations in both pre-and post- MASTEP lessons in which worksheets are used these are supplemented by oral instructions. This may well reflect teachers' appreciation that the text is not in the students' first language and a consequent well established procedure to limit the scope for misunderstanding of instructions and possible hazard.

Nature of student involvement

Teachers plan to involve students actively in practical work. This is true for both the small group work and for larger group demonstrations. With regard to demonstrations, both before and after the MASTEP interventions, the majority of the demonstrations were not mere performances by the teacher. Transcripts show that students were involved in manipulating apparatus, in making observations and in discussing the interpretation of outcomes. For demonstrations in which students were not involved directly with the apparatus there was still classroom interaction. Thus the increased proportion of demonstration after MASTEP does not signal a lower level of student-student or teacher-student interaction, indeed the level of teacher-student interaction during demonstration is higher post-MASTEP.

Conclusions

We conclude that following the MASTEP intervention the balance of teachers' declared purposes of practical activities shifts towards conceptual understanding and to qualitative rather than quantitative outcomes. This is accompanied by a move to the inclusion of a greater proportion of interactive demonstrations. Furthermore, such demonstrations target procedural as well as conceptual outcomes. We attribute such moves to teachers' improved PCK that has enabled them to align their practice with the IGCSE assessment system. While we can relate such changes to MASTEP it remains to be determined if MASTEP teachers can articulate their practice and attribute aspects of this to their MASTEP experiences.

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Appendix

Practical work activities

Modified 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 specific question or problem
(i)	to help students 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 quality	(k)

B1.2 What students are intended to do with ideas		
Report observation(s)		(a)
Identify a pattern		(b)
Explore the relationship 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)
Account for observations	in terms of a given explanation	(k)
	by choosing between two (or more) given explanations	(l)
	by proposing an explanation	(m)

B1.3 Object 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 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 ideas.

B1.4	Degree of openness/closure
(t)	teacher
(d)	discussion
(s)	student

B1.5	Nature of student involvement
(a)	Demonstrated to whole class by teacher: students observe
(b)	Demonstrated to whole class by teacher: students observe and assist as directed by teacher
(c)	Demonstrated sequentially to groups of students by teacher: students observe
(d)	Demonstrated sequentially to groups of students by teacher: students observe and assist as directed by teacher
(e)	Carried out by students in small groups
(f)	Carried out by individual students
(g)	Demonstrated to whole class by student(s) supported by teacher
(h)	Demonstrated to whole class by student(s) supported by teacher

B2.1	Duration
(a)	Very short less than 20 min)
(b)	Short (one lesson, say up to 80 min)
(c)	Medium (2-3 science lessons)

(d)	Long (2 weeks or more)
(e)	Home work activity

B2.2	People with whom students interacts
(a)	Other students carrying out the same practical task
(b)	Other students who have already completed the task
(c)	Teacher
(d)	More advanced students (demonstrators etc)
(e)	Others (technician etc.)

B2.3	Information given to the student on the task
(a)	Oral instructions
(b)	Instructions on blackboard/ whiteboard/ over head projector
(c)	Guiding worksheet
(d)	Textbook(s)
(e)	Other (e.g. data book, database, instruction manual, etc.)

B2.4	Type of apparatus involved
(a)	Standard laboratory equipment
(b)	Improvised laboratory equipment
(c)	Standard laboratory equipment + interface to computer
(d)	Everyday equipment (kitchen scales, domestic materials, etc
(e)	Model

B3.1	**Nature of student's record of work on task**
(a)	No written record
(b)	Notes
(c)	Completion of printed worksheet
(d)	Written account (using given structure and format)
(e)	Written account (free format)
(f)	A model/ artefact
(g)	Drawing or diagram
B3.2	**Purpose of record**
(a)	To assist students in learning science content or process
(b)	To provide evidence that the task has been carried out
(c)	As a basis for assessing the student's performance
(d)	As a record which the student can use to revise for test or examinations
(e)	To help students learn how to writea scientific report
B3.3	**Audience for record**
(a)	The student
(b)	Teacher
(c)	Other students
(d)	Other

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