

The outcomes of practical work: The teachers' perspectives

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Abstract

While literature indicates that there are a number of positive outcomes from practical work in the teaching of science at secondary schools, its usefulness has, however, continued to be under scrutiny. Some researchers still question its suitability. To put it bluntly, not all researchers sincerely believe in the practicality of practical work. Some however still do. For instance, some researchers, at least according to Cilliers, Basson, Kirschner, and Rutherford (2000) still regard practical work as the teaching of practical skills. This is also an issue on its own. With much interest directed at productive reinforcement of the outcomes of practical work, some enthusiastic researchers in Bradley, Durbach, Bell and Mungarulire (1998) have posed serious questions to ponder on about the cost-effectiveness and the purposefulness of practical work. Literal evidence shows that what learners can achieve when they engage in practical work and what the teachers' intentions are with practical work may unintentionally lead to ambiguous conclusions. This is so because this could easily lead to both positive and negative indicators regarding the learners' acquisition of knowledge, skills and attitudes. The study reported in this article explores the teachers' intended outcomes of practical work. A purposive sample of 46 teachers participated in this study. The results of the study shows that the majority of teachers intend to teach the procedure and processes involved in conducting a practical work with few intending to teach the content science.

Introduction

The usefulness and effectiveness of practical work in teaching science at secondary schools is doubted by many researchers. These researchers, according to Cilliers et al (2000) do not believe it can be effective in helping the learners. However, practical work has long played an integral role in secondary school science in industrialised countries (Treagust & Thair, 1999; Tamir, 1991; Hofstein & Cohen 1996; Van der Linder, Van der Wal & Wilkinson, 1994). In countries with a tradition of practical work in school science, such as the UK, practical work is often seen, by teachers and others particularly scientists, as central to the appeal of science (Abrahams, 2009). Consequently, science curricula should contain significant amounts of practical activities and the necessary resources should be provided. This is because, learners learn by doing and thinking about what they do (Lowery, 1994). Thus, the focus should be directed towards facilitating active learning among learners (Coleman, Holcomb & Rigden, 1997).

Generally, some authors (Van der Linde et al, 1994; Allsop, 1991; Bradley et al, 1998, Treagust & Thair, 1999, Abrahams, 2009) all agree that the outcomes of practical work in science focus on the following four broad outcomes. The outcomes are, *reinforcement of the understanding of scientific concepts and principles, development of practical skills, teaching the processes of science as well as stimulating learner's interest.*

Hodson (1992) believes that practical work in school science was previously seen as a means of obtaining factual information or data, many other researchers such as Haslam & Hamilton (2010); Abrahams (2010); Gyllenpalm, Wickman and Holmgren, (2010) unanimously agree that, practical work in schools should assist in the exploration, manipulation and development of concepts and also make the concepts manifest, comprehensible and useful. Hodson (1992) strengthens his argument by stating that experiments should be devised by the learner while the teacher acts as a facilitator. Such a view is in accordance with theories of motivation as confirmed by Wigfield (1994) that recommends ceding a greater degree of control of learning to the learner herself. This is in line with the constructivist theory in Ausubel (1968) which emphasises that learners should construct their own knowledge. This is sadly not always the case as Driver (1989) correctly observes that unfortunately many learners come to science classes with pre-knowledge that is not always acceptable from a scientific point of view. But according to Tamir (1991) and Trumper (2003), practical work can offer unique opportunities conducive to the identification, diagnosis and remediation of learners' misconceptions and alternative conceptions. As a result, Trumper (2003) believes that the teachers (and not the learners themselves) should provide experiences and come up with innovative ways that would help learners confront discrepancies between their own incorrect or limited views and the accepted scientific views.

While the call for scientific literacy as a general goal for science education has emphasised the need for learners to develop an understanding beyond scientific concepts and skills at least according to Gyllenpalm, Wickman and Holmgren some researchers such as Hofstein and Cohen (1996), Millar (1991) as well as Haslam and Hamilton (2010) agree that practical experiences are essential for the development of skills and strategies with a wide range of effects that could be generalised. These practical skills can be divided into three categories (Millar, 1991). The first category refers to general cognitive processes, that is, observing, classifying and stating a hypothesis. The second category is practical techniques that could be specific pieces of know-how about the selection and use of instruments. The third category, which is inquiry tactics is a toolkit of strategies and approaches that could be considered in planning of an investigation. These strategies would include repeating measurement and taking an average, tabulating or graphing results in order to see trends. This means that learners should be helped to improve the use of their creative and critical thinking skills, so that they could become more intelligent and thus learn how to learn. The value of skills in practical work has been traced back from the 70s by Eglen and Kempa (1974) who argue that proficiency in the manipulative skills has generally inferred from the

quality of experimental results normally communicated by the learner to the teacher in the form of laboratory reports. By implication, this practice presupposes that a correlation exists between the proficiency with which a practical task is performed and the quality of the results derived from it.

According to Bentley and Watts (1989) additional skills can be learnt during science practical sessions. For example, learners can learn organisational skills, learn to work independently and cooperatively within a group and also be aware of the time requirements of different tasks like time management.

Tamir (1991) believes that science education should provide learners with real experience of the whole scientific process that is, identifying a problem, proposing possible explanations and devising tests to determine the validity of a particular situation. A successful experience in practical related activities may engender feelings of self-esteem, self-confidence and determination that could be transferable to a wider world outside laboratory. The development of positive attitudes towards science and the scientific enterprise (Woolnough, 1991) is among the major aims of science teaching. While Koballa and Crawley (1985), Bradley and Maake (1998), Bentley and Watts (1989) as well as Tamir (1991) concur that practical work can be an effective environment for enhancing learners' attitudes towards and interest in the learning of science,

On the contrary, the findings by Abrahams (2009) show that practical work generates short term engagement and it is relatively ineffective in generating motivation to study science post compulsion or longer-term personal interest in the subject. In fact, Abrahams (2009) argue that learners' attitudes towards secondary school science become progressively more negative over time, those involved in science education need to develop a more realistic understanding of the limitation of practical work in the affective domain. The study aims to explore teachers's intentions with practical work.

Research questions

What are the teachers' outcomes of practical work?
What are the teachers' views regarding practical work?
How do teachers conduct practical work?

Participants

A purposive sample of 46 Advanced Certificate in Education (ACE) in-service part-time science teachers at a single, urban university in South Africa participated in this study. The teachers were teaching grades 10-12 in the FET (Further Education and Training) band in their respective schools. Subjects taught by this group of teachers include physical science

and mathematics. The highest qualification possessed by these teachers was a three-year diploma in education, majoring in physical science and mathematics.

Research methodology

There are four contact sessions of between 5 and 10 days per year. The ACE programme runs over two years. The study took place during first four contact sessions of their two year programme. In the first contact session the assignment was given to teachers in the first contact session. In this assignment, the teachers were requested to prepare a lesson plan on Ohm's law incorporating the practical component. It was indicated to teachers that their lesson plans should clearly indicate the outcomes of the practical component of their lessons. The teachers were given two months to complete the assignments, where after the assignments were posted to the researcher. Despite the fact that not all teachers who took part in the research posted the assignments in time, the researcher evaluated all the available assignments before the teachers came for the second contact session. The remaining assignments were submitted at the beginning of the second contact session and were also accordingly evaluated.

During the second contact session, individual efforts were combined during the group preparation. The 46 teachers were then asked to divide themselves into six groups. The first and second group consisted of seven members each, the third group consisted of nine members, the fourth group consisted of seven members and the fifth and sixth group consisted of eight members each. Each small group had to compile one lesson from their individual efforts. One teacher in each group presented the lesson while the others role-played the learners. Teachers presented the lessons and their presentations were video-taped. The video-taped lessons were viewed several times and discussed with teachers during the second and third contact sessions.

In the fourth contact session, the presenters of six lessons were requested to prepare a "model lesson", and choose a representative to present the lesson. The "model lesson" was also video-recorded. The teachers, together with the researcher, viewed and discussed the "model lesson". The discussion was facilitated by the researcher. All the video-taped lessons were then transcribed for analysis and coding. A questionnaire was given to teachers to gauge their perceptions of video-taped lessons as a tool in modeling teaching and the intended outcomes of physics practical work.

Theoretical framework

A coding scheme for effectiveness of practical work as proposed by Millar, Tiberghien, and Le Marechal (2002: 13) was modified and used to produce a profile of salient features of practical activities in lessons presented by teachers. Similarities and differences in the kinds of practical work used in lessons were identified. The coding categories were used to suggest questions that science teachers and researchers might ask about practical work. For

example, questions such as the degree of participation of learners in a practical activity and how this compare with the intentions of science teachers were raised.

The coding scheme provides a basis for addressing questions of effectiveness of practical work. In this way we may be able, over time, to progress towards a more effective use of practical work in science at all levels as Millar et al(1999:50) correctly argue. The coding scheme used in this study has two subscales. Sub-scale A of the coding scheme focuses on the teachers' intended teaching outcomes of a practical activity. The teaching outcomes are divided into two main groups, namely content and process. The content is concerned with the learning of some aspect of scientific knowledge, while the process is concerned with learning some aspects of the process of scientific inquiry. Sub-scale B deals with the key elements of a practical activity and is divided into two sections: The cognitive structure of the practical activity (section B I), the level and nature of learner involvement (section B2).

Findings and discussion

Van der Linde at al (1994), Allsop (1991), Bradley at al (1998) and Treagust andThair (1999) all believe that the aims and outcomes of practical work vary in format and presentation and generally views expressed in by teachers regarding the outcomes of practical work correlate with reviewed literature. According to teachers the outcomes of a practical activity as summarised from the assignments fall within five broad themes, namely; the acquisition of knowledge, the development of practical skills, the development of problem solving skills, the development of cooperative learning skills, and the development positive attitudes towards science. The results of the coding scheme are provided in table 1 below. The coding scheme was given to all teachers before the presentation of lesson on Ohm's law. The aim of this coding scheme was to profile features of the practical activity from the teachers' perspectives. The features as proposed by teachers and the views on the outcomes of practical work in their assignments were later compared with the actual implementation in the video-taped lessons.

Table 1: Results of the coding scheme

Sub scale A: The teachers intended outcomes			
To help learners to...		N	%
	<i>identify objects and phenomena and become familiar with them (specify)</i>	22	48
	<i>learn a fact (or facts) (specify)</i>	14	30
	<i>learn a concept (specify)</i>	21	46
	<i>learn a relationship (specify)</i>	32	70
	<i>learn a theory/model (specify)</i>	17	37

	<i>address alternative conceptions (specify)</i>	9	20
	<i>learn how to use a standard laboratory instrument or piece of apparatus</i>	32	70
	<i>learn how to carry out a standard procedure</i>	22	48
	<i>learn how to plan an investigation to address a specific question or problem</i>	22	48
	<i>learn how to process data</i>	24	52
	<i>learn how to use data to support a conclusion</i>	33	72
	<i>learn how to communicate the results of lab work</i>	23	50
Sub scale B1: What the teacher wants learners to do with objects and observables:			
	use an observation	27	59
	use a laboratory device	20	43
	use a laboratory procedure	21	46
	present or display an object	16	35
	make an object	6	13
	make a material	4	9
	make an event to occur	16	35
	observe an object	9	20
	observe a material	0	0
	observe an event	8	17
	observe a physical quantity	28	61
	report observations	22	48
	identify a pattern	16	35
	explore relation between objects	9	20
	explore physical quantities	21	46
	explore objects and physical quantity	22	48
	invent (discover) a new concept (physical quantity)	15	33
	determine the value of a physical quantity	20	43
	test a prediction from a guess	6	13
	test a prediction from a law	21	46
	test a predication from a theory	15	33
	account for observation in terms of a given law	27	59
	account for observations in terms of theory	15	33

account for observations by proposing a law										6	13
account for observations by proposing a theory										4	9
Sub scale B2 Degree of participation:											
	Specified by teacher			Decided by discussion			Chosen by learners			Missing data	
		N	%		N	%		N	%	N	%
<i>Questions to be addressed</i>		23	50		8	17		1	2	14	30
<i>Equipment to be used</i>		28	61		8	17		3	7	7	15
<i>Procedure to be followed</i>		31	67		4	9		3	7	8	17
<i>Methods of handling data collected</i>		22	48		8	17		7	15	9	20
<i>Interpretation of results</i>		6	13		12	26		18	39	10	22

Contrary to teachers' expressions, inquiry and problem solving were not adequately addressed during the lessons. This is because lessons were teacher-centered and the learners were not given a chance to plan an investigation. Although only about 48% of the teachers had said that they would help the learners and show them how to plan an investigation to address a specific question or problem, but overall it was all the teachers who took the lead by instructing learners on the procedure to be followed when doing investigation. Learners would wait for instructions on what to do next. For instance, the teacher would say, "Now connect two cells and record the readings from the ammeter and voltmeter".

It is expected that learners should make predictions in inquiry-science classrooms. These predictions should lead learners into making thorough observations in order to inquire and explore concepts such as potential difference, current and resistance.

Expressions of teachers differed from those expressed in the coding scheme and lessons presented by teachers. The teachers, in the assignments, were asked to write general outcomes of a practical activity in science and the coding scheme as well as the lessons according to Ohm's law. About 70% of the teachers said that they intended helping the learners learn how to use a standard laboratory instrument or piece of apparatus (in this case an ammeter or voltmeter). The teachers' intended outcome was later confirmed in the video-taped lessons. The teachers in the lessons focused on the use and purpose of the ammeter and the voltmeter. This was done through asking questions on both the voltmeter and ammeter. For example the teacher in one of the lessons asked the questions as follows:

Teacher: I want you to look at the instruments with symbols A and V. What is the one with A?

Learner: It is an ammeter.

Teacher: What is the function of the ammeter?

Learner: It is to measure the amount of current.

Teacher: How do you connect the ammeter?

Learner: You connect it in series.

Teacher: What is the name of the other instrument with a symbol V on it?

Learner: It is a voltmeter.

Teacher: How do you connect the voltmeter?

Learner: You connect it in parallel.

A number of teachers (about 61%) said the equipment to be used would generally be specified by the teacher. This was done as a way to introduce the lesson to the learners. The lessons focused on testing the learner's pre-knowledge through question and answer method. The experiment used in this study (Ohm's law) is based on the relationship between the current and the potential difference. It is for this very reason that 70% of the teachers said they would help learners to learn a relationship. A conclusion that can be derived from this practical activity is that there is a direct proportionality between the current and the potential difference, provided the temperature remains constant. Through instructions from the teacher, the learners were instructed in one of the lessons to: *"take readings from the ammeter and the voltmeter, I will now give you the worksheets to record your readings."*

Similarly, in one of the lessons, the teacher said, *"In activity 2 we are going to do an experiment to verify Ohm's law."* This implies that the teacher's main outcome was to confirm Ohm's law through a teacher instructed lesson. In addition, about 46% of the teachers intended that learners should test a prediction or law, in this case Ohm's law. Learners generated data during the practical activity on Ohm's law and 72% of the teachers' intended teaching outcome was to help learners to learn how to use data to support a conclusion. Although data compiled from the worksheets was supposed to be used by learners to support their conclusion, the teachers, instead, discussed the experimental data with learners and made a conclusion by saying: *"This is what we normally call Ohm's law. If the potential difference between points in the conductor increases, the current increases."*

Furthermore, the teachers in one of the lessons concluded by drawing the graph of potential difference versus current from the data obtained by learners and then asked the learners to, *"give the relationship between potential difference and current in verbal form."*

A very low percentage of teachers (about 20%) intended to address misconceptions. These may be due to inadequate knowledge and awareness by teachers of the misconceptions that both teachers and learners may bring to the classroom. Some of the teachers displayed misconceptions in the video-taped lessons. For instance one of the teachers said, *"The current is flowing from positive and is looking for negative, can you see it?"* The teacher gave

learners an impression that they can see electric current in the circuit. A very positive aspect about the video-taped lessons is that almost 95% of the teachers realised after viewing the tapes that, video-taped lessons could help to address alternative conceptions.

At least 46% of the teachers said that their intention was that learners should use a laboratory procedure. In addition, 48% of the teachers intended learners to carry out a standard procedure. These procedures were indicated in the worksheets provided by the teacher. As a result, learners ended up following a recipe given to them by their teacher and not planning how they go about doing the practical on their own. The researcher believes that the latter may impact on the development of inquiry and problem solving skills of learners. The results are in accordance with research findings by Olney (1997), who argues that the approach used by teachers is a "cut and dried" laboratory procedure, which minimises learner participation.

The results show that 67% of the teachers would specify the procedure to be followed in the experimental task. This approach was evident in the video-taped lessons. The teachers in the lessons specified and instructed learners to follow procedures indicated in the worksheets, while the teachers' focus was on teaching Ohm's law theoretically. Only about 7% of the teachers said they would allow learners to choose the procedure to be followed, while at least 9% said the procedure to be followed would be decided by discussion. This further indicates a more teacher-centered approach. Half of the teachers, that is 50%, said that they would specify the questions to be addressed in the experimental task. All the teachers asked questions in the video-taped lessons. The nature of the questions asked was not problem-based and inquiry-oriented. Some of the questions were, "*how do we connect the ammeter?*" and the learners would respond by saying: "*in series*".

The study indicated that in most of the lessons learners did not give a convincing account of the observations made. Instead, they depended on the theory provided by the teacher. Similarly, a very low percentage, about 9% of teachers intended learners to account for observations by proposing a law. In the video-taped lessons learners were asked either to state Ohm's law or let the teacher dictate it to them. For instance, the teacher would say "*If the current increases, potential difference increases. If current decreases, the potential difference decreases. This is what is called Ohms law*".

About 48% of the teachers said that methods of handling data collection would be specified by the teacher. In the video-taped lessons the experimental data was recorded in the worksheets. In all the lessons the teacher instructed learners on how to handle data. This may impact on the development of learners' manipulation skills. The same percentage of the teachers (48%) intended learners to report observations. This was done in the worksheets provided by the teachers. Learners were supposed to record and report observations. Presenters in the lessons were tempted to report and give an analysis of the

observations to learners, for instance one of the teachers plotted the graphs displaying the relationships between potential difference and the current on the flipchart and said, *I want to see if you are going to get the same pattern.*" The same percentage (48%) of the teachers intended learners to explore relations between objects and physical quantities. This simply implies that the lessons were more teacher-centered.

Overall, the results indicate that higher percentages of the task will be specified by the teacher. This also indicates a more teacher-centered approach. Only 13% of the teachers said that the interpretation of results will be specified by the teacher, while an overwhelming 39% said that the interpretation of results will be chosen by the learners and at least 26% said that the interpretation of the results will be decided by discussion. The video-taped lessons indicate that teachers tend to interpret the results of the experiment for the learners.

A total of 57% of teachers said that the experimental task would be carried out by learners in small groups. While, the majority of the teachers, a whopping 63% believed that the learners would interact with the teacher. About 54% of the teachers said that learners would interact with other learners carrying out the same lab work task. The researcher's observation in the video-taped lessons is that teachers put learners in groups but do not facilitate the groups to fully participate and work cooperatively.

The results indicate that about 65% of the teachers use textbooks as information sources available to learners. This is because most schools do not have the necessary apparatus to perform practical work in physics. Only a paltry 17% of the teachers use a computerised database and they probably do not use it for physics practical work. The results indicate that teachers' approaches are mostly textbook-oriented and worksheet-driven and this was evident in all the lessons.

Conclusion

The focus on the outcomes of teaching and learning as Van Rensburg and Potloane (1998) state, is on what learners know and what they can do at the end of their learning experience. The article investigated what teachers view as outcomes of practical work. Although the outcomes of practical work from literature emphasise reinforcement of the understanding of scientific concepts and principles, development of practical skills, teaching the processes of science as well as stimulating learner's interest. The majority of the teachers' intended outcome with a practical on Ohm's law was to help learners to learn how to use data to support a conclusion. In addition, the practical component as viewed from the video tapes shows that their approach to practical activities was teacher-centered. The focus of their practical activity was to specify the equipment to be used and further ask learners about the function of the equipments. The results of this study indicate that

teachers were quick to make conclusions from the practical activity without giving learners an opportunity to make such conclusions on their own.

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