Eğitim ve Bilim
2005, Cilt 30, Sayı 136 (61-67)

Education and Science
2005, Vol. 30, No 136 (61-67)

A Review on the Practical Work in School Science

Fen Derslerindeki Pratik Çalışmalarla İlgili Bir İnceleme

Yezdan Boz and Nihat Boz
Middle East Technical University and University of Warwick

Abstract

Although practical work is a major component of science education, it is questionable whether it is used effectively in science classes or not. This article provides a critical review of practical work in science education by discussing the nature of practical work in schools. It is concluded that practical work, which is used in the context of suitable teaching styles, where students can relate to their learning, will be more beneficial to the students than the practical work in which students are led "cookbook" style through a set of instructions.
Keywords: Practical work, science education.

Öz

Pratik çalışmalar fen eğitiminde oldukça önemli bir yere sahiptir; ancak, bu çalışmaların fen derslerinde etkili bir biçimde kullanılıp kullanılmadığı tartışmaya açıktır. Bu makalede, fen derslerindeki pratik çalışmaların nasıl kullanıldığı tartışılacak, bu çalışmaların fen eğitimindeki yeri eleştirel bir yaklaşımla incelenecektir. Sonuç olarak, etkili öğretme stilleriyle kullanılıp öğrencilerin öğrenmesine katkı sağlayan pratik çalışmaların, yemek kitabı gibi basamakların takip edildiği pratik çalışmalara göre öğrenciler için daha faydalı olacağı vurgulanacaktır.
Anahtar Sözcükler: Pratik çalışmalar, fen eğitimi.

Introduction

It is well known that practical science is a prominent feature of school science teaching in many countries. However, there are different opinions on whether or not practical work is used effectively in science classes (Woolnough, 1991). This article is based on an account of the role of practical work in science education mainly considering the nature of school practical work. Firstly, the role and nature of teaching styles in science education will be discussed. Next, the necessity of practical work in science education will be discussed. Finally, the nature of practical work in school science will be described.

Yrd. Doç. Dr. Yezdan BOZ, Orta Doğu Teknik Üniversitesi, Ortaöğretim Fen ve Matematik Alanları Bölümü, Ankara. e-mail: yezdan@metu.edu.tr

Dr. Nihat BOZ, University of Warwick, Mathematics Education Center, Coventry, UK. e-mail: nihatboz@yahoo.co.uk

Role and Nature of Teaching Styles in Science Education

There are many different teaching styles described in the literature. Lecture, demonstration, discussion, role play, simulation, laboratory, project, small group work, individual work are amongst the most common or popular styles. The group size, motivation of the students and what teachers want their students to achieve are the important issues affecting teachers' choice of appropriate teaching styles. For example, if a teacher wants to link theory with practice, hands-on experiments or demonstration can be helpful. If it is a crowded classroom, we think that demonstration would be more sensible.

While we are suggesting such teaching styles, we are aware of the fact that teaching and learning processes involve complex issues. However, it should be pointed out that there are some views generally accepted by educators and psychologists about how students learn and how they should be taught. Two general and prominent theories about learning and teaching are behaviourism and constructivism.

Behaviourism is generally described as a theory that regards learning as occurring through the transfer of information from teachers to students. That is, behaviourists think that pupils are empty vessels that can be filled with information. Therefore, behaviourism gives importance to conditioning students on how to behave when they encounter problems and questions. Direct teaching where students are told what to do and how to do problems is one of the favourite teaching styles in behaviourism. While teachers are transferring such information, the students are expected to stay passive and absorb the provided information. On the other hand, constructivism emphasizes that students construct their knowledge by actively interacting with their environment. That is, learning occurs when students are actively involved in the process. Therefore, constructivism regards the teacher as a guide and a facilitator who help students to construct their knowledge.

The educational theories we briefly explained show that teaching styles can affect what students learn and how they should be taught. Therefore, appropriateness of the practical work as a teaching style may depend on teacher's view about teaching and learning.

For example, hands-on experiments provide an opportunity for pupils to carry out their own experiments either individually or in groups in science classes. These experiments can be beneficial if teachers can direct pupils to do something constructive rather than allowing them to just stand or gossip during dead time, that is, the time spent waiting for something to happen such the boiling of water in practical work. To exemplify, pupils might usefully discuss in groups what is happening in the experiment on a molecular level and then each group can present their ideas at the end of the experiment (Parkinson, 1994). This is also supported by the theory of constructivism. As Shiland (1999) explains, cognitive development occurs through social interaction, which can produce an environment where the ideas of individuals are shared. This can be provided in practical work by allowing pupils to discuss their predictions, procedures and to present their ideas. Discussion may cause cognitive conflict. Therefore, pupils should discuss and share their ideas during the practical rather than just following the procedure of the experiment.

Necessity of Practical Work in Science Education

In order to understand the necessity of practical work in science education, it is important to know what science means and what the purposes of science teaching are. According to Ratcliffe (1998), science looks for explanations of the natural world. Understanding the natural world begins with curiosity. Scientists can use many scientific methods to understand the natural world; they may formulate hypotheses, design experiments and make observations. These inquiries can lead to the development of a new product. Creativity and imagination play an important role in science and it depends on certain skills such as observation, classification, interpretation skills, skills required to record and analyse scientific data, handling the scientific equipment and materials, etc.

It can be understood from the above explanations that science requires certain skills to understand the world. The aim of science education should be to reflect on these issues and these aspects of science should also be taught at schools alongside the theoretical part of science. According to Wellington (1989), a process-led curriculum would make science more interesting and accessible to pupils since it becomes less content based and abstract. Another reason for process-led curriculum is that scientific facts are forgotten or remain as disconnected knowledge if not implemented. Therefore, scientific skills such as observation, classification, planning, reasoning which may be of value in pursuit of other learning, would be useful. This is because of the fact that an aim of science should be to cope with new developments in the future. Also since technology is improving very rapidly, one can understand that teaching of those skills linked to generating knowledge rather than teaching facts only would be more beneficial.

Furthermore, the science curriculum should not only develop the curiosity of pupils about the natural world but also build up their confidence in investigating the behaviour of the world (Millar & Osborne, 1998). The science curriculum should help students to understand key concepts of science and use procedures of scientific inquiry to solve problems. As a result, it can be suggested that practical work constitutes a major aspect of the science curriculum. Moreover, practical work may be of use in motivating pupils, developing curiosity and helping pupils to acquire scientific skills.

The Nature of Practical Work in Science Education

The aims of practical work in the view of teachers and educationalists can be summed up as;

- promoting the understanding of scientific facts and theories through the help of concrete experience;
- increasing the motivation of pupils,
- understanding the scientific approach in order to solve appropriate problems,
- developing specific skills and
- developing scientific attitudes such as open-mindedness and objectivity. (Hodson, 1993).

The above aims are parallel to the aims of science teaching. However, it may be wondered whether in schools, the practical work is used in a way that fulfils these aims.

Research aimed at finding out pupils` views about practical work using questionnaires shows that pupils associate practical work with the development of manipulative skills, increasing interest and discovery of new things and testing ideas. Similarly, pupils view practical work as being useful only in the school context. They do not see its relevance to the life outside the school (Denny and Chennell, 1986a). Other research of Denny and Chennell (1986b) having the same aim, but using letter-writing and drawing exercises as the research instrument to explore pupils` views about practical work illustrates that children see practical work as a teaching device to reduce boredom, develop self-esteem and understand scientific theory within a confirmatory rather than an investigatory mode. A summary of these research findings suggests that students' views about practical work are not completely in accordance with its aims. That is, pupils` views reflect a restricted part of the purposes of practical work in science. In the following sections, we will explore in depth how practical work is used in schools through considering its five aims separately under different headings.

Motivation

Practical work does not always motivate or increase pupils` interest as teachers expect (Hodson, 1990). Pupils view the practical work as a less boring activity compared to the other teaching methods (Harlen, 1999; Gardner and Gauld, 1990). Children regard practical work as an opportunity to talk more freely with the teacher and other children in the class. It was found that 57% of children said they liked practical work; however 40% said they did not like it when they did not know what they were doing (Hodson, 1990). Therefore, it may be suggested that the practical work in schools does not in fact motivate students. One of the reasons why practical work does not fulfil its 'motivation' aim is because the pupils are not helped to understand the purpose of the experiment.

Motivation of pupils can be improved when pupils are given more independence in practical work (Monk and Osborne, 2000). We suggest that the pupils may be given more independence by providing them with the chance to design their own experiments or decide how to collect and arrange data. We think that this issue is, to some extent, related to the constructivist view of teaching. Since pupils should be responsible for their own learning and the teacher should act as a facilitator to guide pupils in their constructions, independence in practical work may not only increase pupils` motivation, but also provide a chance for the pupils to restructure their knowledge towards "the accepted". However, in most cases, teachers design the investigation and pupils follow the procedures given by the teachers (McIntosh, 1995). Such a procedure in which teachers design the experiment may make the students passive in learning and this may decrease their motivation.

To sum up, it can be claimed that practical work is not implemented in schools in a way that it motivates students. Therefore, it is suggested that teachers should help students to engage in the experiments more actively in order to increase their motivation. It is commonly agreed that motivation can help students to understand scientific facts. Nevertheless, we still need to find answers to the question of whether or not the practical work at schools really aids in understanding scientific facts. We will explore this issue in the next section.

Understanding scientific facts

Research shows that practical work does not help much in helping pupils to understand scientific facts. For example, Hodson (1990) reports that practical work does not contribute much to understanding scientific facts when compared to the other methods of teaching. This view is supported by other studies such as Dillon, Prieto and Watson (1995) and Hodson (1993).

One of the reasons for getting such results may be related to how practical work is applied in the schools. As we mention in the previous section, during practical work activities, students are not helped to be engaged actively by increasing their motivation. This view is parallel to Tugel's (1994) findings that show that practical activities in schools are generally "cookbook" style; students need to follow only the procedures. Therefore, these activities do not help pupils to develop their skills such as creativeness, critical thinking and planning; students finish the activity without understanding the purpose of the experiment. Moreover, most students saw the purpose of the experiments quite different from their teachers or do not understand it at all (Woolnough, 1991). From these research results, we deduce that the application of practical work in schools is not resonating fully with its aims. Such a misapplication of practical work in schools prevents students from learning what is intended. Thus, these issues raise the question: "What needs to be done to remedy the current situation?"

We suggest that teachers should play an important role in making the practical work a tool to improve pupils` conceptual understanding. For example, teachers may encourage pupils to think about what they are doing and why they are doing it while using the practical work. In this way, practical work may help pupils to understand the theory. The pupils may also be allowed to write out the procedure themselves for the teacher to check rather than getting it from the teacher. We believe that such a free environment will help pupils to understand what they are doing.

It should also be remembered that the expectations of pupils affect the way they observe and interpret these observations in the practical work. Encouraging pupils to discuss the experiment through mainly open-ended questions may set clear prospects for students (Woolnough, 1991). That is, discussions help students understand what to expect from practical work activities. We think that this not only helps students to link the practical work with the theory in that context but also creates a discussion environment where students' expectations are identified and shared. Therefore, we think that practical work may be useful to enhance pupils` learning of scientific facts when it is used in line with its aims. In this case, it can be used as one of a range of appropriate teaching styles that could improve students' understanding.

Scientific Skills

There are controversies surrounding the definition of 'scientific skills'. Wellington (1989) states that there is uncertainty over what are meant by the term 'skill' and there are variations in the terminology of processes, skills and process-skills. However, agreeing with Hodson (1990), we must mention that there are two kinds of laboratory skills we can help pupils to acquire; the generalizable and transferable skills, and the skills required by scientists and technicians. The former skills are not related to the content and not valuable for all pupils since these can be applied also to non-laboratory situations. On the other hand, the latter skills are related more to the content.

In the context of practical work, we find Woolnough's (1991) categorization helpful: general cognitive processes, practical techniques and inquiry tactics. While general cognitive processes include observation, classification, reasoning, planning skills; practical techniques involve the skills necessary to use equipment, read the measurements and carry out standard procedures such as separating a solid and a liquid by filtration. Inquiry tactics, on the other hand, are the skills such as repeating measurements, graphing results to see the relationship or identifying variables to measure, control and the like. Whatever the terminology used to explain the skills above, we think that the important point is whether or not practical work can really be of use helping students to acquire the skills explained above.

The research reports that investigate whether practical work is of use to teach these skills are not very cheerful either. For example, Hodson (1990) reports that practical work does not help pupils to acquire these skills. It was found that 11% of children at age 15 can read a pre-set ammeter correctly and only 14% can set up an electrical circuit. We think that this is a quite interesting finding. It shows that very few of the students who are taught through practical work acquire its aims. We suggest that such a result may be caused due to possibility that only very few students in the group used to conduct the work and the others were not so interested. If this is the case, then very few students actively involved in the practical work activities, while remaining students stayed passive.

On the other hand, we should recall Hodson's (1990) claims about these disappointing results of the research cited above. She (1990) claims that certain skills only are required for pupils to complete a practical activity successfully and there is no need to teach all skills. Skills, which will be valuable in order to pursue learning, should be taught in separate training sessions before the lab session rather than expecting that pupils will learn these during the experiment. Teachers should ensure that these skills are developing to a satisfactory level of competence. When students encounter a practical activity requiring certain skills which are not necessary to pupils, this practical work should be presented in a different way. For example, demonstration, pre-assembly of apparatus and the like can be incorporated in the practical activity. Support for this view comes from Woolnough (1991) who suggests that practical work, which involves difficult tasks for pupils such as apparatus assembly or connecting of the required circuit, can inhibit pupils of learning the theory part of the experiment. This is because students concentrate on the completion of these difficult tasks rather than nature and implications of the observation. In order to help students to concentrate on the observation, devising different practical such as demonstrations can be of use. This will give pupils the chance to spend more time interacting with ideas and less time with the apparatus. As a result we suggest that school practical work needs to be rethought critically in terms of its effectiveness to provide scientific skills.

Scientific Attitudes

Open-mindedness, willingness to consider evidence, objectivity and other similar features can be counted in scientific attitudes. These attitudes are expected to be met by the practical work in the curriculum according to the assumption that scientists have these attitudes (Harlen, 1999). However, it should be acknowledged that scientists do not possess these characteristics; they are often illogical and often insist on their views despite contradictory evidence (Monk and Osborne, 2000). On the other hand, Hodson (1990) mentions that characteristics of scientists differ from each other and there are two kinds of scientist; extreme speculative scientists, who can build a theory without any data, and data-bound scientists, who depend on data to make a theory. It should be remarked that there are different ways of thinking also among mathematicians:

> It is impossible to study the works of the great mathematicians, or even those of the lesser, without noticing and distinguishing two opposite tendencies, or rather two entirely different kinds of minds. The one sort are above all preoccupied with logic; to read their works, one is tempted to believe they have advanced only step by step, after the manner of a Vauban1 who pushes on his trenches against the place besieged, leaving nothing to chance. The other sort are guided by intuition and at the first stroke make quick but sometimes precarious conquests, like bold cavalrymen of the advanced guard.
>
> (Poincaré, 1913, 210)

All these bring into question the necessity of trying to teach open-mindedness, willingness to consider evidence, objectivity and other similar features, if characteristics of real scientists may differ from each other. Even if these attitudes are thought necessary to teach, practical work at schools does not promote such attitudes. This is caused by the fact that practical work is controlled by the need to get correct answers and to find out what ought to happen to ensure consistency with the answer in the textbook (Hodson, 1993). When what a student observes differs from what is expected, he/she can change his/her observation to fit the correct result. Therefore, practical work becomes a tool used to confirm the correct results in the textbooks rather than to investigate something new. In order to alleviate this problem, the students can be provided with unfamiliar experiments that do not have results in the textbooks. Furthermore, students should be encouraged to find different results at the end of experiments and to discuss the reasons for finding different results in such cases.

Scientific Approach

The necessity of finding the answer in the textbook at the end of practical work also causes pupils to misunderstand the scientific approach. When they find different results from the expected ones, they are often told that they did something wrong by the teacher. This reflects the view that scientists know the right results before doing an experiment, which is wrong (Hodson, 1990). As Storey and Carter (1992) mention, students should not view experimental or observational results as facts since single or even repeated experiments not often result in definite answers to the questions asked in science due to different factors affecting the results. To illustrate, when the pH of tap water is measured, one can get the ranges of pH of 5.0 to 6.5 due to faulty electronics, an inaccurate electrode probe or improper calibration.

In addition, students memorise steps of scientific methods through five steps, which are "state the formal hypothesis, design the experiment to test the hypothesis, collect data, analyse data and draw the conclusions" (Storey and Carter, 1992). However, this is not the way scientists do their research. They begin by asking questions instead of a hypothesis and observations or experiments follow this. In addition, they do not always carry out experiments to answer this question. They may collect material, make observations. To this extent, practical work in schools gives pupils the wrong impression of the scientific approach.

As understood from the above explanations, school practical work may be useful if it is used to fulfil its aforementioned aims. However, different aims can be fulfilled by different kinds of practical work. For example, certain manipulative skills can be developed through the help of group or hands-on experiments. Demonstration can be also helpful, if it is used as an aid to clarify the scientific concepts. If students are expected to understand the scientific approach, we think that investigations or more open-ended tasks would be more helpful.

As well as these, it should be remarked that there may be other factors for the teacher in choosing a certain practical work. For example, if an experiment includes hazardous materials or steps for pupils to carry out; a demonstration may substitute the practical work or time constraints can result in not doing investigations.

Conclusion

Research findings about practical work show that it does not increase the motivation of pupils, promote their understanding of scientific facts, understand the scientific approach to solve appropriate problems or develop certain skills such as skills required to handle the equipment, observation, critical thinking. In short, the practical work is not used in schools in a way that it fulfils its aims.

There are several reasons for such disappointing results. For example, most students are not told the purpose of the experiments beforehand. Furthermore, since practical activities are generally "cookbook" style, students need to follow only the procedures. Therefore, "cookbook" style activities do not motivate students and therefore develop pupils` skills such as creativity and critical thinking. Hence, students cannot relate practical work to their learning.

Furthermore, students think that there is only one correct answer or result they need to get at the end of practical work. We think that teachers should encourage students to discuss the reasons of different answers they may get. There has not been much research into practical work carried out in Turkey. Research of Pekmez (2000) indicates that most pupils in Turkish secondary schools experience few practical work classes. There are several reasons why practical work is not a widespread teaching style in Turkey. Two of these reasons are the lack of resources and very large class size. Another reason may be that practical skills are not assessed by an examination. Instead, there is a university entrance exam at the end of secondary school, which assesses knowledge. Pupils are expected to pass this exam if they want to continue their education at university. Therefore, the curriculum mostly tries to address the issues related to this examination rather than the practical work. Similarly, pupils see the practical work as less valuable than scientific facts or formulas since they are expected to know these well if they want to attend a good university. In our opinion, the inadequacy of resources may be partly solved by preparing a circus of activities for pupils.

Another alternative to solve the resource problem is to engage pupils in practical activity through the use of cheap instruments. For example, simply candles alone, which are very cheap, can help to address many chemistry concepts such as changes of state, melting and boiling points, energy transfer, burning fuels, burning hydrocarbons and exothermic reactions (Swain,1999).

Students should be helped to relate the practical work to their learning and also to understand the process of discovery. In our opinion; even cheap resources and demonstrations can be of use to relational learning if they are used with a teaching style to make pupils think. To exemplify, pupils may be encouraged to predict what will happen when variables are changed in an experiment by requesting explanations for underlying reasons for their prediction. We think that practical work used in line with aforementioned teaching style will help the pupils make more sense of what they are doing when compared to the cookbook style. Therefore, in our opinion, the crucial point is the teacher rather than the practical work itself. That is, the practical work itself does not guarantee to fulfil its aims if it is not tailored according to the needs of the students.

References

Carter, J. & Storey, D. R. (1992). Why the scientific method?: Do we need a new hypothesis? *The Science Teacher,* 18-21.

Chennell, F. & Denny, M. (1986a). Science practicals: What do pupils think? *European Journal of Science Education, 8* (3), 325-336.

Chennell, F. & Denny, M. (1986b). Exploring pupils` views and feelings about their school science practicals: Use of letter-writing and drawing exercises. *Educational Studies, 12* (1), 73-86.

Dillon, J., Prieto, T. & Watson, J. R. (1995). The effect of practical work on students` understanding of combustion. *Journal of Research in Science Teaching, 32* (5), 487-502.

Harlen, W. (1999). *Effective science teaching: A review of research.* Edinburgh: SCRE.

Hodson, D. (1990). A critical look at practical work in school science. *School Science Review, 70* (256), 33-40.

Hodson, D. (1993). Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education,* 22, 85-142.

Lock, R. (1990). Open-ended, problem-solving investigations: What do we mean and how can we use them? *School Science Review, 71* (256), 63-72.

McIntosh, C. T. (1995). Problem-solving practice: Challenging students to design experiments and organise data. *The Science Teacher,* 48-50.

Millar, R. & Osborne, J. (1998). Beyond 2000: Science education for the future a report with ten recommendations. Retrieved 25 July, 2002 from the World Wide Web: http://www.kcl.ac.uk/depsta/education/be2000/be2000.pdf.

Monk, M. & Osborne, J. (2000). *Good practice in science teaching: What research has to say.* Buckingham-Philadelphia: Open University Press.

Parkinson, J. (1994). *The effective teaching of secondary science.* London and New York: Longman.

Poincaré, H. (1913), *The foundations of science* (translated by G. B. Halsted). New York: The Science Press. (page references as in University Press of America edition, 1982).

Ratcliffe, M. (1998). *ASE guide to secondary science education.* London: Stanley Thornes.

Shiland, W. T. (1999). Constructivism: The implications for laboratory work. *Journal of Chemical Education, 76* (1), 107-109.

Swain, J. (1999). Rediscovering the candle. *Education in Chemistry,* 130-134.

Tugel, B. J. (1994). Pollution, pH and problem solving. *The Science Teacher,* 21-25.

Wellington, J. (1989). *Skills and processes in science education: A critical analysis.* London and New York: Routledge.

Woolnough, B. (1991). *Practical science.* Milton Keynes-Philadelphia: Open University Press.

Geliş	19 Şubat 2004
İnceleme	1 Mart 2004
Düzeltme	13 Aralık 2004
Kabul	7 Şubat 2005