Procedural understanding: teachers perceptions of conceptual basis of practical work

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PROCEDURAL UNDERSTANDING: TEACHERS' PERCEPTIONS OF CONCEPTUAL BASIS OF PRACTICAL WORK

by

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Abstract

This is a study, which attempts to identify the ideas of science teachers about procedural understanding on a conceptual basis.

The principle means of data collection was interviewing science teachers, in England and in Turkey, about their views of practical work in the dimension of procedural understanding. Some classroom observations involving practical work were also conducted to see teachers' actual practices. With the analysis of all data, it is hoped that findings would be utilised in informing a new science curriculum and a newly-designed teacher education programme in Turkey. The findings from English teachers suggest that their perceptions of procedural ideas are not as adequate as expected by the requirements of the National Curriculum. The results also present general views of Turkish teachers on practical work, which show that they have no knowledge of procedural understanding. Accordingly, the study concludes with some suggestions for more effective teaching.

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It all began with me being full of fears on an untypical sunny day in Durham. It was like a restart of my academic life, struggling to know more about the world of science education. (I thought the struggles would end after completing this thesis but actually they only begin now.) Luckily, I had my supervisors Richard Gott and Philip Johnson. I can never thank them enough for their generous help and support throughout my journey. They made me rethink and analyse ideas by reading and offering suggestions for every chapter of this thesis. Apart from their help in reading the thesis, I also owe special gratitude to them for their support and encouragement when I had difficulties in this country.

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DECLARATION

This thesis results from my own work and has not been offered previously in candidature for any other degree in this or any other university.

STATEMENT OF COPYRIGHT

1 Introduction

In school science curricula, the issue of practical science has been considered an important factor in every country. However, the emphasis on and the understanding of it are different in different countries. For instance, having seen the examples of two countries, England and Turkey, and having reviewed the literature, it is seen that England has generally had a greater emphasis on practical work as part of science education for over one hundred years. Given such an emphasis, it is also now a part of an assessment procedure called Sc1, which is one of the Attainment Targets. To this researcher, a non-British outsider, it seems that everything is stated perfectly in the National Curriculum. Everything which pupils should be taught about science seems to be included. Basically, this everything should include the science education aims, which rely on the effectiveness of teaching science. They are 'helping students understand the concepts of science as in learning theories or laws' (this is defined 'substantive understanding'), and 'the process of science as in learning what to do and basically what to do to obtain these theories' (this is defined 'procedural understanding' in this research). These two aims are very much related (figure 1.1). When people believe that theories or laws can be learned without practical work, then the discussion of the use of the progress of science itself, in other words the discussion of the value of practical work, begins. The outcome of the majority of discussions

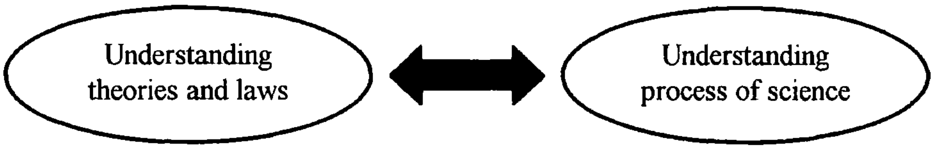


Figure 1.1: Main aims of science education

is that practical work must be done. Another discussion thus begins regarding the real value of practical work, as in the contribution of practical work to the learning process. What does practical work teach apart from or before contributing to the learning process? And is practical work being taught the way it should be? For instance, are the expected standards of pupils' performance, stated in the National Curriculum as the first attainment target, actually being taught by the teachers? To answer these questions, the understanding of teachers should be known. Basically, this involves an understanding of the procedural ideas, as detailed in the next chapter. It should also be known if the teachers understand these procedural ideas. In summary, procedural understanding includes the process of designing an experiment in full detail and obtaining reliable and valid data on which to base conclusion, as do professional scientists. This study attempts to reflect on the perceptions of teachers, since their ability to teach these ideas relies on their own understanding of procedural understanding.

As previously stated, it seems clear that in the National Curriculum the learning requirements have been clearly outlined. What does not seem too clear is how teachers arrange to teach procedural ideas in their classrooms. What are their classroom practices? What meanings do they attach to practical work, especially investigative work? The guiding principle was to seek to understand the ideas of procedural understanding from the perspective of teachers. This would be essentially the grounding for developing a new science curriculum. It is believed that taking into account teachers' ideas, as much as students', will be necessary for curriculum development. The focus of this study will be on the teachers' perspectives on practical work in terms of what it teaches and in terms of what teachers teach children during practical activities.

That kind of information would be necessary and helpful before developing a new curriculum, and will also be helpful when considering a new teacher training programme in Turkey. Both teachers and those who are responsible for training teachers need to know clearly what to teach and why to teach it. Knowing their ideas about this will also give ideas about what practice might look like. This study is therefore of particular interest to me as I will be one of the members of the teacher-training programme. The use of practical work in school science in Turkey is still quite rare, but there is a willingness to develop such strategies. I feel, therefore, that the challenge of creating better science education must begin. Thus, I consider it a necessity for me also to have a better understanding of the nature of change and the requirements of practical work, for the intention is to provide a platform for the teacher training programme in Turkey. A clear understanding of teachers' approaches to practical work seemed a valuable opportunity to consider and incorporate their ideas.

The next chapter reviews the related literature in England and in Turkey in two separate sections. Each section includes developments of science education related to practical work, with a summary of history. It also analyses some recent research studies carried out with teachers regarding the understanding of the concepts underlying practical work. Characterisations of practical work from the researchers' and teachers' points of view will therefore be presented briefly. The characterisations include purposes and types of practical work, problems which arise, and England's Attainment Target 1 and procedural understanding. The chapter also gives a brief description of the attempts that have been made to remedy science teaching, and the endeavours, especially in Turkey, to improve the quality of teacher education.

Chapter 3 introduces a brief overview of the methodology of the research as well as the research purposes. Detailed information of the design of the interview questions, the interviewing processes, and analysis of the responses are given.

Chapter 4 outlines the responses of the teacher survey and gives the results of the classroom observations in both countries. The findings are categorised as purposes and types of practical work, time that the teachers spend on practical work, and difficulties with investigative work and problems they are having. Tables will illustrate which areas of procedural understanding the teachers actually talked about. Thus, areas of teachers' understanding will be clear. Finally, as a result of the classroom observations the data about teachers' actual practice will be presented, again from a procedural point of view.

Chapter 5 discusses the findings in detail and explores the nature of teachers' perspectives relating to the literature. According to the research findings, the teachers do not really understand the knowledge underlying procedural understanding, and the chapter examines possible reasons for this situation.

Finally, chapter 6 summarises the conclusions reached in the survey, and provides specific recommendations as a result of the feedback.

2 Literature Review

This chapter focuses mainly on a review of literature related to the teaching of science in both England and Turkey, with emphasis on the theories and development of practical work as a tool in science teaching, and perceptions of its usefulness. The issues to be addressed are the characterisations of practical work from the researchers' or teachers' point of view in England and Turkey. That is the reason this chapter includes two separate sections: practical work in the UK and practical work in Turkey. In each section I will give a brief summary of what is going on in both countries. I will first give an historical perspective and then identify particular issues, which affect the curriculum. It should be noted that since both countries operate different systems, this will be reflected in the section's overall structure. An attempt shall also be made to briefly describe the teaching of science in these two countries.

2.1 Section 1 / Practical Work In The U.K.

2.1.1 History of the development of pupils' practical work

The history of the development of pupil 'hands on' practical work starts with Armstrong's 'heuristic' approach or 'finding out/discovery' method in the late nineteenth century (Thompson, 1956). Before this, any practical work was limited to teacher demonstrations to illustrate substantive content. This approach encourages the involvement of students as much as possible in finding things out by themselves instead of merely being told about things. It was Armstrong's view that pupils must go to the bench so that they can gain the ability to use practical techniques themselves (Armstrong, 1896: cited by Gott and Duggan, 1995). He believed that good science teaching is investigative; promotes scientific method. Because of the influence of Armstrong's approach, by the close of the 19th century, class practical work had become a part of the English school science curriculum (Gee and Clackson, 1992).

However, at the beginning of the 20th century the heuristic movement was beginning to become unpopular (Gott and Duggan, 1995). The Board of Education circular, at the time, promoted the idea of demonstration and placed less emphasis on children's individual experiments (Uzzell, 1978). Similarly in 1918 there was a report of a committee set up by the Prime Minister of the time. According to this report, individual practical work was considered to be a waste of time, the report also suggested that it would be more economical to return to a situation where demonstrations were performed by the teacher just to illustrate substantive content (Clackson and Wright, 1992). It seems that they were ignoring the importance of hands-on practical emphasised by Armstrong. In 1937, however an edition of the Handbook of Suggestions produced by the Board of Education stressed that science teaching should help students to understand the method of science, gain scientific habit, understand the interrelationships among facts and draw appropriate conclusion from evidence from practical work (Uzzell, 1978). Similarly another report by The Science Master's Association in 1938 stressed that a child should be able to explain principles from fact and hypothesis, to plan experiments, and to draw conclusions. It also encouraged practical abilities like accurate work and the application of science to solve practical problems via empirical skills. Thus, this report emphasised points relating to procedural knowledge as well as substantive knowledge. This emphasis led to some research on the effectiveness of individual practicals. For instance, it was found that individual lab work was more effective than demonstrations in terms of developing simple manipulative skills, measuring techniques, and the knowledge of apparatus (Kruglak, 1952 stated in Clackson and Wright, 1992). Of course, it is not surprising that pupils would have better manipulative skills when they do practicals themselves.

In 1947 a joint committee of the Incorporated Association of Assistant Masters and the Science Masters' Association published a book entitled 'The Teaching of Science in Secondary Schools', it stressed the value of accurate observation, good practical techniques and the critical assessment of experimental results. In 1953 'Secondary Modern Science Teaching' was published in which active experimenting and discovery methods were encouraged (Uzzell, 1978). Pupil practical work was continually supported throughout the 1960s and early 1970s with almost all the major science curriculum developments in these years promoting hands-on practical work as an enjoyable and effective form of learning (Hodson, 1990).

One of the highlights of the 1960s was the development and introduction of the Nuffield Project, which focused on biology, chemistry and physics. Understanding scientific processes was considered more important than just learning the facts. Also, the discovery approach to practical work was seen to be crucial. It saw that the substantive principles should first be established through practical work. The intention was to get pupils to think about scientific things within a discovery approach. The Nuffield Schemes seems to have been influenced by Armstrong's heuristic campaign, which gave both inspiration and enthusiasm to the people who worked in the Nuffield team. The Nuffield Project had a great effect, by the mid-1980's more than 20 books/projects in science and maths had been produced and published (Gordon and Lawton, 1984). However, it must be recognised that a large proportion of the practical work carried out by pupils in these decades was of a 'recipe' driven kind. This would now be called 'traditional' practical work, where the purpose was to illustrate substantive content (in the same way that demonstrations had been employed in earlier times).

The Assessment and Performance Unit (APU) was set-up in the late1970s and part of its brief was to examine practical work in schools and its assessment (Lock, 1988). At the same time a major survey of science education in secondary schools was conducted by HM Inspectors and according to them in about one-third of the schools the teaching of all science was always over-directed, to the detriment of sufficient activity of pupils (DES, 1979, stated in Hodson 1992a). Similarly in a report published nine years later (DES, 1987), concluded that although practical work was carried out, it had given few opportunities for pupils to design investigations. Practical work was given prominence in school science in the form of 'investigation' with the introduction of the National Curriculum (AT1) (DEF, 1995).

2.1.2 Attainment Target 1 - At1 (Sc1)

In the National Curriculum, there are attainment targets for each subject and for science, of the four attainment targets this study is related to the first one (AT1/Sc1), which describes the levels of understanding of experimental and investigative science.

The National Curriculum has included investigations in the curriculum since its formal inception in 1989 with the requirement that pupils originate and undertake their own scientific investigations. In 1991, a Revised Version emphasised individual pupil investigations. According to the National Curriculum, by the end of each Key Stage, pupils of different abilities are expected to have some knowledge, skills, and understanding of specific tasks. These are identified within the National Curriculum, things which pupils should know, understand and be able to do. Mainly, the first target include (DFE, 1995)

1. to use scientific knowledge and understanding to identify the key factors in situations involving a range of objectives and, where appropriate, to make predictions, systematic observations and measurements with precision using a wide range of apparatus,
2. to identify when they need to repeat measurements and observations in order to obtain reliable data,
3. to present qualitative observations clearly and concisely, and to present data in graphs, where appropriate, and also use lines of best fit,
4. To draw conclusions that are consistent with the evidence and explain these using scientific knowledge and understanding and to begin to consider whether the data they have collected is sufficient for the conclusions they have drawn.

Also in AT1, a scientific investigation is defined as an open-ended task, where pupils decide what apparatus to use, what observations or measurements to make and how to evaluate. In summary, the whole process of investigating an idea should include planning experimental procedures and obtaining evidence, which are explained by following first and second item above; analysing evidence and drawing conclusions; and evaluating the evidence. This should be carried out by pupils themselves. These criteria are to be taught and assessed within the National Curriculum. They became compulsory and pupils were being assessed according to their knowledge of procedural understanding. It was (is) believed that this should be a necessary part of science teaching.

As mentioned before there has been a fundamental change in the way science is taught in schools, the catalyst being Armstrong. Since the 1960s, many attempts at curriculum development have been made and this has been mainly due to innovation schemes such as the APU and Nuffield. It has been realised for some time that pupils should find out things using scientific process in order to understand the knowledge that underpins procedural understanding. Since then procedural understanding has been one of the major research subjects in the science education community. So what is purpose of practical work?

2.1.3 The Purpose Of Practical Work

It was reported by APU (DES, 1985) that almost all school science courses in England, Wales and Northern Ireland place emphasis on practical work. This section, among other things will attempt to account for the reasons why there was such an emphasis placed on practical work.

2.1.3.1 Educationalists' views

As noted earlier, there are two main aims for science teaching: (1) helping students understand the concepts of science i.e. learning theories or laws, (2) learning what to do and basically how to obtain these theories; i.e. establishing the relationships embodied in laws and explored by theories. The first one is related to the substantive side of science, and the second one is related to procedural side of science.

Driver (1983) is of the opinion that in terms of pupils' understanding, lab work makes the subject more understandable for them. It extends pupils' knowledge of phenomena, illustrates and confirms accepted principles. Also practical work makes pupils gain some experience in planning an experiment and using their own initiative. On the other hand, Woolnough and Allsop (1985) described the aims of practical work as developing practical skills and techniques, being focused on problem solving and finding out real phenomena which has more emphasis on procedural understanding.

Gott and Duggan (1995) argued that different types of practical work should be matched with principal learning outcomes. The types are skills, observation, enquiry, illustration, and investigation. Respectively the aims are

1. to acquire a particular skill;
2. to provide opportunities for pupils to use their conceptual framework in relating real objects and events to scientific ideas;
3. to discover or acquire a particular concept, law or principle,
4. to prove or verify a particular concept, law or principle,
5. to provide opportunities for pupils to use their concepts, cognitive processes and skills to solve a problem. It is to establish whether a relationship exists or not. This leads to giving importance to quality of data.

Having mentioned classification, Wellington (1998: 12) suggested that in a typical science lesson, we should see four types of event going on: teacher demonstrations; class practicals - with all learners on similar tasks, working in small groups; a circus of experiments - with small groups engaged in different activities, and finally investigations.

Some believe that to develop manipulative skills with basic scientific apparatus is an essential function of practical work (Woolnough and Allsop, 1985; Campbell and Wilson, 1998; Wellington, 1998, Gott and Duggan, 1995). They also believe that this can only be successful by allowing students to experience it with the materials, apparatus, and phenomena. Later, Woolnough (1998) stated that experiments are to enable students to develop and use their personal knowledge through experience. Lastly, he added that experiments are to motivate students towards science - motivating, by encouraging them to follow their own enquiries.

2.1.3.2 Counter Arguments

There are some counter arguments as well as the arguments about the benefits of practical work. For example, most educators believe that practical work improves pupils' understanding and verification of theories. Wellington (1998) stated that if practical work went wrong then it could confuse ones' understanding and so it is not a good tool for teaching. He argues that theory comes first before the practical.

Additionally, from interviews and action research in the classrooms with teachers and pupils in KS3, Duveen et. al. (1993) also found that the ability of pupils to make connections between theory and experiments developed very slowly.

It could be said that practical work is motivating and exiting, and that it helps learners to remember things. Qualter et. al. (1990:5, stated in ibid.) claim that this is not the case when practicals go wrong or when pupils cannot see the point of doing a certain experiment.

Another study (in both England and Spain) investigated 14-15 year old students' understanding of combustion, and explored the effect of practical laboratory experience on students' understanding. A major difference between the two countries is the amount of practical work done. They found that in England, about 60% of lessons involved the whole class doing practical work, about twice as much as in Spain. The research tried to find what impact practical experiences had on students' understanding of combustion (Watson et. al. 1995). According to the results of their study, lab work seems to have made a small impact on the English students' understanding of combustion. It appears that most students failed to use the knowledge gained through lab work to modify their explanations of combustion and the extensive use of practical work done by the students had only a marginal effect on their understanding of combustion. In the literature there is not much similar evidence that says that experimentation does not actually work in terms of substantive understanding but neither is there evidence to suggest that it does. The whole literature on children's substantive ideas has shown that understanding of pupils is very poor. This suggests that if it is to be effective, it is the quality and not the quantity of the practical experience that counts. However, procedural understanding might be given attention of itself, rather than simply as a means to understanding e.g. combustion. With the quality of experiences, the importance might be better given to the procedural understanding as well as the substantive understanding.

To summarise, the consensus for doing practical work is actually the specific aim of science education, i.e. acquiring mostly conceptual and then procedural understanding. It is all accepted by the science education community that practical work is necessary. Teachers' thoughts play a vital part in how they encourage practical work with the pupils. In addition, most importantly, as a result of teachers' application pupils' learning is therefore affected. It is more important to know about the ideas of the teachers who actually put this concept into practice. The next section considers teachers' views.

2.1.3.3 Teachers' Views Of The Aims Of Practical Work

There is a consensus in support of the fact that teachers' role is central and crucial to effective education (Kelly, 1990). Millar (1998) stated that the role of the teacher is to guide the learner, by proposing activities, providing well-chosen materials, and drawing attention to salient features. In this sense it is important to have the teachers' view of practical work. From the most recent literature, now, I will present the teachers' reasons for including practical work in their science classes.

Within the National Curriculum Council (NCC) project 290 teachers filled in a questionnaire which was designed to probe teachers' understanding of AT1 in the general context of practical work in science (Gott and Duggan, 1995). The project was carried out just after the introduction of the National Curriculum, which includes AT1. In this survey teachers were asked to order five possible aims for practical work. These turned out to be: concept illustration and consolidation, raising questions and devising solutions, observation, concept discovery (enquiry), and skills (these were stated before as the aims of practical work.) (Gott and Duggan, 1995). The results showed that, at the infant teacher level most of them said observation, at the junior teacher level the emphases was on raising questions and devising solutions, and at the secondary level it was concept illustration.

Research by Wilkinson and Ward (1997a,b), examined students' and teachers' perceptions about the purpose and effectiveness of lab work at Y10. 25 teachers and 139 students constituted the sample to be surveyed. It was aiming to compare the perceptions of a class of students with their teachers' perceptions with regards to lab work. The teachers and students were asked to rank ten listed given aims of practical work in order of most importance like the Likert scale. In order of ranking, these are given below:

- To make science more interesting and enjoyable through actual experience
- To enable students to discover or verify facts and ideas for themselves

- To gain practice at making accurate observations and interpreting them
- To promote thinking in a scientific way
- To help students understand theoretical parts of science
- To develop skills in working co-operatively with others
- To give training in solving problems and conducting investigations
- To gain experience in using scientific equipment
- To give practice in following a set of instructions
- To prepare students for examinations

Similar research was done by conducting questionnaires for teachers and pupils to find out the role of practical work in science education (Campbell and Wilson 1998). Questionnaires had open-ended and yes-no questions for teachers. The questions were asking about their classroom practice and reasons for employing practical work. No examples of questions were given. The findings indicated that teacher's use of practical work to motivate and to help pupils' understanding. A number of teachers claimed that the acquisition of lab skills and the development of investigative abilities were important aims of practical work. No information was given about what the teachers meant by investigative abilities. If we summarise the findings from their work, the teachers' reasons for including practical work in science lessons are as follows. 1- it is interesting and enjoyable, 2- to develop lab skills, 3- it helps understanding and learning, 4- linking theory and application, verification of laws, 5- to develop scientific approaches, 6- to encourage and increase questioning, and 7- it adds variety. They found that practical work was also seen to be required to be undertaken to prepare pupils for the assessment of their investigative abilities as required by the National Curriculum. These findings are almost the same as the ones identified by Hodson (1993a). In addition, some years ago, Keightley and Best (1990) found that teachers considered theoretical understanding more important than practical skills. It seems that the main emphasis has been on the substantive understanding. There is little information on the procedural understanding and teachers consider supporting theories and motivation as the most important aims of practical work.

However, the teachers' views do include both substantive and procedural approaches. Teachers made mention of lab skills, raising questions, and solving problems. We need to know what they mean in terms of deciding if the emphasis, stated as AT1 (or Sc1) in the National Curriculum, which is on the investigative side of the practical activities are being put into practice by teachers. Do they really reflect the National Curriculum? This research will also attempt to give some answers on that. After giving some information about the views of teachers it is also important to know what kinds of problems that identified by research that they are having. This will be discussed in the next section.

2.1.4 Problems identified by the research

The problems can be divided into two. Problems about what teachers actually say, which is mostly about the conditions in the schools, and the problems about teachers' understanding and application of practical work. For example, Wilkinson and Ward (1997a) reported that the most common problems in the conduct of lab work were related to poor conditions, insufficient equipment and the long preparation time. They concluded that such problems tend to reduce a teacher's desire to conduct more lab work. Regarding time, there is criticism that practical work is too time consuming and teachers have difficulty in fulfilling the requirements of the science curriculum within the time limits (Barton, 1998).

Apart from the practical difficulties, it seems that the most important problem is the teachers' understanding of science. Gott and Duggan (1995) found out that there has been a tendency for teachers to accept that doing practical work regularly is a good thing without thinking about its purpose or learning outcomes. Lederman (1992) and Munby (1982) reviewed a number of surveys on teachers' conceptions of the nature of science (which ultimately rests on procedural understanding). According to the conclusions, science teachers do not possess adequate conceptions of the nature of science. Ryder et. al. (1999) did a longitudinal interview study with 11 science students in their final year at university to find out the images of science which undergraduate science students hold. Again it is found that these future teachers were confused about the understanding of science. Nott and Wellington (1999) investigated the views of pupils, students, teachers, advisers, and inspectors on school science at key stage 3 and 4 by conducting a survey. Data were collected from teachers by means of questionnaire (308) and interviews (22). Two of the main issues were investigations and practical work, and the teaching of the nature of scientific ideas. For instance, teachers used practical work not because they found it effective (in terms of helping understanding) but because pupils expected it.

Investigations are seen as more about getting marks than learning the nature of scientific ideas. It is stated that there is a lack of confidence in teachers to teach them. As a result it seems that teachers' views should be developed before or this could lead to the consequence of misleading pupils in science teaching by conducting practical work.

Kelly (1990) made a critical review in his book about the National Curriculum. He indicated that 'teachers had little or no say in what they were to teach or in what kind of curricular provision they make for their pupils. The only scope they had is in relation to the methods they could adopt to deliver the content of a curriculum which had been determined elsewhere'. Perhaps if teachers were included in curriculum planning, their inadequate understanding of science would be different. According to this statement it is like teachers are the patients obeying a doctor's prescription.

Teachers' beliefs and understandings need to be considered and understood, before more work and decisions can be made related to areas such as the curriculum. This study will highlight some ideas of the teachers' views about practical work. First the ones in England will be focused on since there is much emphasis on practical work already. With this information new attempts can be discussed in Turkey on the ground of the teachers' experiences before introducing new ideas. Due to the fact that only limited research about this issue has come out of Turkey have led me to do this research using England as an example.

There are some areas of research findings about teachers' views of AT1. This shall be the next area of focus.

2.1.5 AT1/Sc1 – Investigations

As stated before, the NCC project included a questionnaire which was designed to probe teachers' understanding of AT1 in the general context of practical work in science (Gott and Duggan, 1995). As a consequence, it was found that the word investigation was being used to describe a range of practical work as the aim of investigations given by the teachers were learning skills or processes, concept discovery, use or refine concepts, raise questions or test ideas, enjoyment or motivation, and observation. Another finding by Duggan and Gott (1996) showed that teachers also saw the purpose of investigations as the determination of relationships between variables.

Having believed that Sc1 leads to a range of problems including difficulties in the classroom practice of generating, organising and assessing pupil-led investigations, in their use of assessment criteria and in the accessibility to all the pupils, Donnelly (1995) conducted a research, in order to find teachers' views about Sc1 as a result of their experience. In his study, he interviewed 31 teachers (in 10 schools) and undertook some classroom observations. It appeared from the results that although there are some positive views, most of them had negative ideas about Sc1. For instance, negative ideas are about investigations being compulsory, assessing pupils or managing the class. The practices of teachers -which were not stated- were found to be incongruous to mismatching what AT1 states. Accordingly, he came to the conclusion that since it is compulsory, Sc1 mapped out arrogant, prescriptive road and believed that this is the reason why teachers were feeling deskilled.

From surveying teachers' opinion through interviews and by three questionnaires Donelly et. al. (1996, p.151) stated that the supply and organisation of materials was a problem. For example, a teacher said that "we have set ourselves up to do all this whole investigation, student-based learning, but we haven't got the resources to do it, we set ourselves up for failure and that's not good for the kids, it is not good for me".

Another argument against Sc1 investigations was the issue of time, which is allocated to investigations within schemes of work; and the time which is devoted to pupils for writing up their work. The time is considerable for the activity of students conducting their own investigations as in collection of data, - identifying the variables and selecting and using the instrument (Donelly et. al. 1996). Osborne (1998) argues the devoting considerable time to the activity of students conducting their own investigations. It is a long process of collection of data- identifying the variables and selecting and using instruments; choosing an appropriate means of presenting data, assessing its reliability, validity and evaluating the implications; planning and doing the experiment, writing up, interpreting, and presenting the findings, and evaluation. He questions the major warrant for devoting so much time to such practical tasks, 'when' will pupils need such skills? It could be argued that pupils will need those skills all the time in order to understand the nature of science.

Wilkinson and Ward (1997b) interviewed 25 teachers and 139 students about the issue (details of methodology was given before). Research showed that only 30% of teachers encouraged students to design and conduct their own experiments and only 20% of students thought they were encouraged. During interviews most teachers stated that they only encouraged their more capable students to design experiments.

The next section will give the information about procedural understanding beginning with concepts of evidence (Gott and Duggan, 1995) which is a conceptual content that is very much related to the procedural understanding.

2.1.6 Concepts of Evidence

These are listed below (Jones and Gott, 1998, p:765).

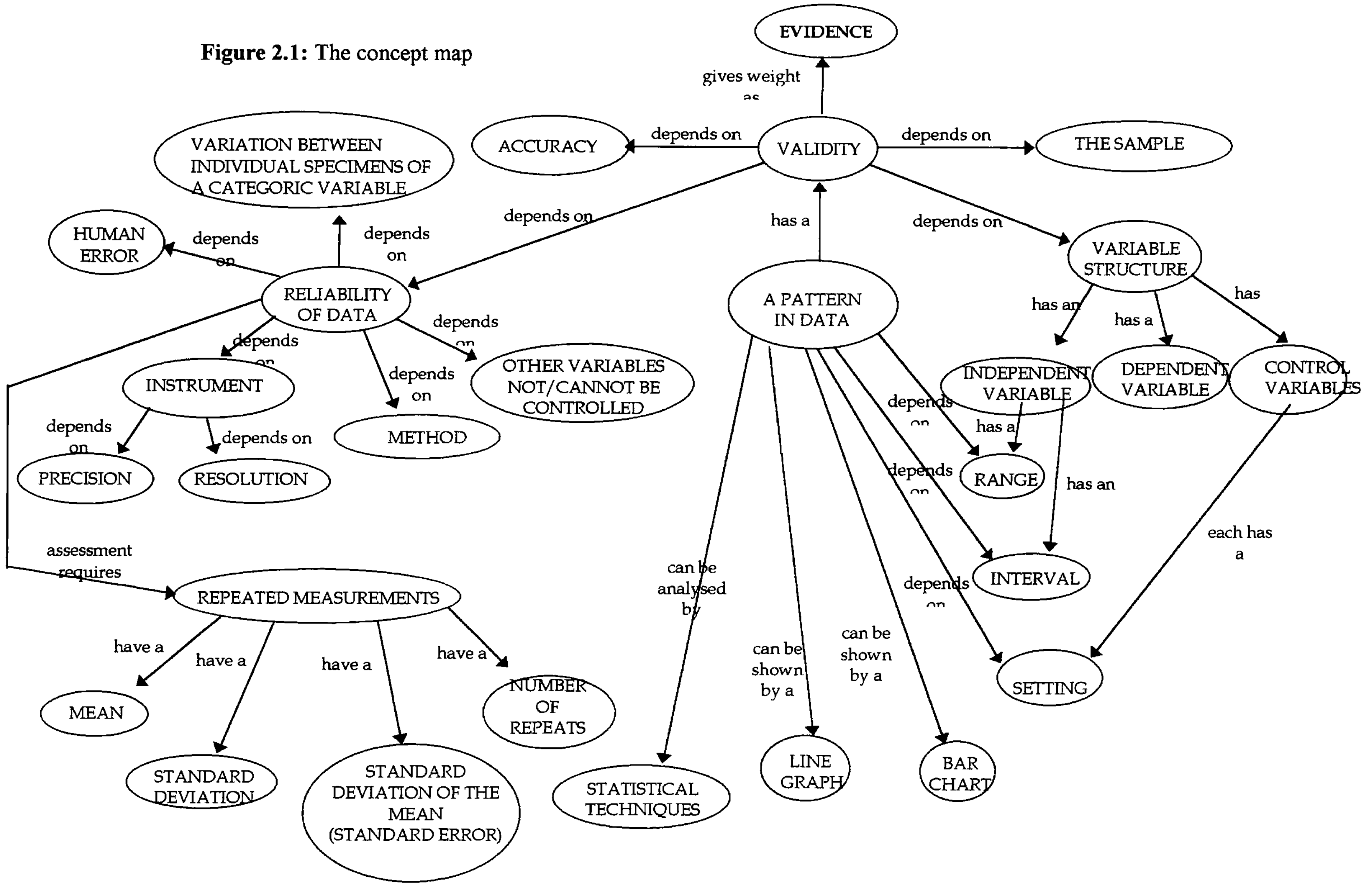
- *Variable identification:* independent and dependent variables, which define the experiment.
- *Variable types*: categoric, discrete, and continuous.
- *Fair test*: controlling variables and the controlling experiments in biology.
- *Range and interval*: choosing sensible values to pick out.
- *Sample size* and its effects on the estimate of population characteristics.
- *Relative scale*: choosing sensible quantities to give accurate data
- *Reliability* of the whole experiment through sensible choices of variables, instruments etc.

- *Choice of instrument* to give the necessary sensitivity, accuracy and repeatability.
- *Repeatability*: repeating measurements (sampling the behaviour) to get an estimate of the errors.
- *Accuracy* and how it linked to ideas of repeatability, choice of instrument etc.
- *Tables*: their use as organisers.
- *Graph types* and their link to the nature of the variables.
- *Patterns*: collecting sufficient information to portray the pattern in a relationship and understanding the reliability of that pattern.
- *Multivariate data*: the effect of many independent variables and the ways of separating out the effects
- *Validity*: the ability to judge a complete task and to ensure that it is in fact answering the question.

Figure 2.1(p26) is a concept map which has been drawn using the list as a basis (Johnson, 1999). There are some differences in detail, however, the key point is that this represents a content of ideas in the same way that concept maps can be used to represent substantive content. These ideas are necessary to being able to judge the quality of data: to assess whether the data are good enough to establish a particular relationship or not (a fact or law which is the basis of the theory). As such they underpin an understanding of how scientific method generates knowledge.

Traditional illustrative experiments rely on the acceptance that the data are

Figure 2.1: The concept map



reliable and valid. The 'established' facts and laws which are the basis of theories (i.e. substantive knowledge) depends on this procedural understanding. A key question is whether these underpinning ideas have been sufficiently recognised in science education. Gott and Duggan (1995) argue that the specific purpose of investigations (as introduced in AT1/Sc1) should be to develop children's understanding of concepts of evidence. Only with this view in mind does the purpose of investigations make sense. As written, although many of the terms listed earlier (page 24-25) appear in the specification of Sc1, it is not explicit that these apply to a conceptual content which needs to be taught, rather than processes to be 'picked up' somehow by 'doing'. There is also the issue of whether the area has been well enough mapped out.

Roberts and Gott (1999) conducted research which examined some work done by biologists. They found that, statements in Sc1 (at least for biology) showed that 'many of the ideas necessary to a thorough understanding are either not stated explicitly or are missing' (understanding as in procedural understanding which will be described next in detail). They concluded that the National Curriculum does not enable teaching to reflect the practice of the empirical biologist and believed that some important ideas were missing. These important ideas should allow pupils to acquire the 'procedural knowledge' and understand them as part of the scientific process.

If one accepts that issues surrounding the quality of data are important, and that one needs experience of collecting data in order to develop an understanding of the issues, then practical work in the form of investigation has a place in the curriculum in its own right.

Gott and Duggan (1995) have developed a taxonomy for procedural understanding, which is given below. For pupils, it aims to improve understanding, application and synthesis of concepts by enabling pupils to carry out whole investigations and put their understanding into practice.

Procedural Taxonomy:

- *Knowledge and recall of skills* such as the use of a thermometer.
- *Understanding of concepts of evidence* as in the understanding of the role of the fair test or the range and number of readings required in measurements of temperature.
- *Application of concepts of evidence* (in unfamiliar situations). It is the ability to apply the notion of the fair test in all experimental work.
- *Synthesis of skills and concepts of evidence.* It is, for example, the links between a fair test and the validity of any resulting data, or between the accuracy of a set of readings and the reliability of the data.

Gott et. al. (1999) believe that procedural understanding is a central issue in science and is essential in problem-solving. It is also likely to be particularly relevant wherever science is used in the workplace in applied science. If there are any problems with the general understanding and the understanding of procedural knowledge they suggested that this fundamental problem is due to a lack of recognition by both curriculum developers and teachers by the significance they attach to procedural understanding.

It is believed that carrying out investigations provide opportunities for pupils to synthesise substantive and procedural understanding. A model developed from Gott and Duggan (1995) based on Gott and Mashiter, (1991) showed the interaction between substantive and procedural understanding (figure 2.2.)

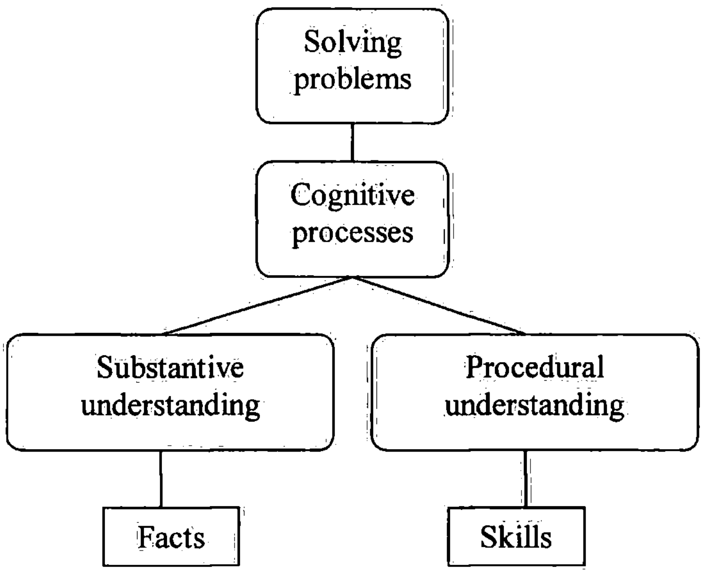


Figure 2.2: A model for using both understandings for problem solving in science.

Solubility, saturation, solvent, solution, and concentration for instance are some of the facts and ideas that pupils should know on dissolving, in using their procedural knowledge in an investigation. Then they should use their cognitive skills such as by observing different materials when they dissolve.

2.1.7 Summary: different approaches to practical work

The table below gives a summary of the different approaches to practical work. It contrasts their relationship to substantive and procedural understanding.

Approach	Substantive Understanding	Procedural Understanding
Traditional	To illustrate and develop pupils' understanding of substantive content.	Major emphasis is on how to use and on developing manipulative skills. No attention to the quality of data.
Discovery	Pupils to discover the substantive content for themselves.	Manipulative skills + basic experimental design + drawing conclusions. However, little attention to the ideas needed to judge the quality of data. There is a 'right answer'.
Process	Substantive content is independent of the processes.	To identify and practice the processes of being a scientist. Little attention to the quality of data. The processes are seen as rituals.
Investigation	Understanding of substantive content is integral to the investigation.	To develop pupils understanding of concepts of evidence. The conclusion rests on judging the quality of data – there is no 'right answer'.

With the focus on the quality of data, we can see that investigations are introducing a distinctive purpose for practical work. We can illustrate the common issues concerning procedural understanding, in school science in the list below (adapted from the concept map, figure 2.1). It basically explains the main structure of the procedural understanding. In order to reach the aim of Sc1 pupils should at least learn that structure (which includes five main areas). According to this, pupils should learn how to do a fair test, to decide the range and the interval of the independent variable, and setting of the control variables. To make the data reliable, they should be aware of the importance of choosing the instrument, and the method, repeating measurements, and especially in biology, choosing the right sample. In order to make a sound conclusion they should be able to draw tables and then present the result by a line graph or a bar chart. These ideas underpin Sc1 in the English National Curriculum (and indeed, any experiment which claims to show a relationship), the question is whether this procedural conceptual content is recognised by teachers. This contents can be listed below:

1. Fair test
2. Decisions and trials
3. Reliability of data
4. Sampling
5. Presenting data

The first four issues relate to validity.

Understanding what teachers are thinking is important in terms of teaching because the aspects of the National Curriculum should be very much depends on the views of the teachers. They are supposed to lead students to explore and investigate science and to develop an understanding of scientific investigation. There is evidence to suggest that teachers' perceptions are one of the main factors affecting children's performance in practical work (Gott and Duggan, 1995). This is the reason why it is important to know teachers' attitudes to their scheme of work. 'What is their understanding of procedural understanding?' This research will attempt to explore this further. Recent studies have not explored teachers' understanding of ideas, which underpin procedural understanding which is about quality of data; they have been rather general. They have not really specifically focussed on teachers' understanding of these ideas which were given as a map on page 43. This research, this time, is aiming to give emphasis on these specific ideas. Below, the statement of the research purposes is given with details.

2.2 Section 2 / Practical Work In Turkey

2.2.1 Development of the Turkish Secondary Science Curriculum

Ayas et.al. (1993), in their article, discussed the problems encountered in the historical development of the Turkish secondary science curriculum. A group of researchers who were appointed by the National Ministry of Education concluded that during the period 1923-1960, the secondary science curriculum was based upon textbooks - theoretical knowledge was dominant. The same group was also appointed to examine the educational systems of some developed countries such as the US, Japan, Britain, Germany, Italy, and France. The main aim was to integrate new ideas into the educational system of Turkey, this happened in 1959.

Between 1960 and 1984 there were some initial attempts to make science teaching more practical, establishing laboratories for schools was one of the ways. In 1964, a science lycee was established in Ankara, the capital. The aim was to use this lycee as a pilot centre for the implementation of 'new' innovations in science teaching and so The Commission of Development in Science and Mathematics Teaching (a body in the Board of Education) was established in 1967. The members of this commission were from the teaching staff in the science departments of the universities in Ankara. The responsibilities of these members were as follows (Turgut, 1990):

1. translation and adoption of foreign curricula (American),

2. in-service teacher training,
3. dissemination of the curricula,
4. formative and summative evaluation of the curricula.

After the pre-pilot of curricula in the science lycee, the commission decided to extend the pilot study to the nine other general lycees. During the pilot studies reports from teachers' and inspectors' and group discussions among evaluators and teachers, as well as students' achievements were incorporated. As a result, they implemented the project in 200 lycees. An extended revision of all aspects of the curricula-from textbooks to in-service programs- was recommended but the National Ministry of Education could not by itself provide the funding needed. It is stated that this was one of the reasons that caused the adapted science curriculum to be abandoned in 1984.

After the demise of the foreign curriculum, there was another attempt by the Council in the Board of Education to develop a new curriculum. In contrast to the previous one, the members of this council were mainly teachers and inspectors from the National Ministry of Education. The commission had written up textbooks by making use of some of the content and objectives of the abandoned curriculum. The new syllabus for the new curriculum was published in 1985. It was stated that the syllabus had to be followed by teachers without any addition.

2.2.2 Ministry of education (MEB), science curriculum until the age of 14-15, 1995.

Under the Turkish science curriculum, it is believed that science explores the reasons for all phenomena. In saying so, the curriculum must have the ability to encourage pupils' curiosity and create interest. Other aims of the curriculum are, (i) to explain the reasons of a phenomena, (ii) teaching pupils to make predictions, to hypothesise, plan and do experiments, (iii) to make observations, record the results after observations, (iv) to classify and analyse data. In the curriculum it is suggested that in order to teach certain concepts pupils should do experiments first by themselves and teachers should help them afterwards. However, it is not especially stated that it is a kind of discovery approach. The actual aim is to make pupils active.

It is written that under a teacher's guidance, pupils should do simple experiments in an investigative way (when it says investigation, it does not mean the same as in Sc1. It mainly means carrying out experiments for themselves). The whole purpose of this is for pupils to understand scientific methodology: i.e. aims (ii) to (iv) above. Pupils are expected to use scientific methods while doing experiments, and learn laws and theories. They are expected to present data in a graphical way, and to evaluate, and draw conclusions. They should understand the importance of using specific equipment in a proper way and to develop their skills in how to use them. This stance is supported by MEB, (1995b) which states that 'pupils should be able to use the equipment such as thermometers, compass, battery etc' and 'these are the skills that should be taught and developed'.

2.2.3 Reorganisation of the teacher training program

The courses in Schools of Education are 4-year graduate programmes and they are supposed to train students to become teachers. However, the overwhelming emphasis was on subject knowledge, as the lecturers have mainly been supplied from science faculties. Apart from some general knowledge of education, graduates are as qualified as the graduates from science faculties. Therefore, it could be said that graduates from the schools of education are full of theoretical knowledge about their subjects (physics, chemistry, and biology), but lack the vocational training of being a teacher. It was believed that this lack of training condemns teachers to the talk and chalk method rather than the development of their teaching abilities. Thus newly qualified teachers lacking practical knowledge are facing many problems and obstacles when in the workplace. The process of teacher education can be criticised in many aspects such as the quality and the content of the courses and inefficiency of the practical training period. Up to the present day, with changes yet to come, the situation was like this.

In order to increase the quality of the teachers, a project called the 'National Education Development Project' (NEDP) has come up with some new ideas aimed at a reorganisation. The key point was that the duty of the Schools of Education should be to train student teachers to become qualified teachers. Information about this project is given next.

2.2.3.1 YOK/World Bank National Education Development Project/NEDP

(Source: The British Council)

The project, which has a duration of three years is funded by the Government of Turkey via the World Bank. The project started in December 1994 and was administered by the Higher Education Council (YOK) of Turkey.

2.2.3.1.1 The scope of the project

The objective of the project was to improve the quality of teacher training at primary and secondary school levels. Institutions involved in the project included all university faculties of education, which provided four-year undergraduate courses (which is students' first degree) leading to qualifications in primary and secondary school teaching.

2.2.3.1.2 Constituent parts of the project

The project had three major parts which worked together in supporting the development of teacher education. Here are the strands:

1.*Curriculum development*: The aim was to produce a new curriculum in the methodology of teaching in each subject area. The new curriculum was embodied in books, which were written by the consultants working within their subject areas. The chemistry book is given as an example later in this chapter.

2.*Fellowship*: About ninety fellowships had been awarded mostly for masters and doctoral degrees so that on completion of their degrees, they will return to their own faculty with the experience of a different system. It was hoped that they would be ready to contribute to the further development of teacher education in Turkey. I too myself am part of this project and I hope that this thesis will meet the objective of the project.

3.*Equipment*: Most of the equipment needed for the new curricula was supplied for the schools of education and for primary and secondary schools all over the country.

2.2.3.1.3 YOK/World Bank, NEDP, Pre-service teacher training program/chemistry teaching

(Source: the web page of the Higher Educational Council in Turkey, http://www.yok.gov.tr, march/1998. Authors: A. Ayas, S. Cepni, D. Johnson and F. Turgut)

For each branch, a committee prepared a book. Apart from the authors this committee involved lecturers from different schools of education. The details in this book are going to be presented and related to practical activities, in order to view the new system's objectives about science teaching with particular regard to practical work.

The aim of the science teachers, related to practical work is categorised as follows. Teachers should

1. Lead students to investigate by encouraging them to ask 'why', 'how' and 'what if' questions.
2. Encourage them to make observation in order to make students use investigative methods (i.e. 'hypothesising').
3. Encourage students in activities that requires them to explain phenomena (like asking why, how, questions and do that by investigating the relationship between 'cause' and 'effect').
4. Make students to be able to plan an experiment.
5. Encourage students in activities that they can help develop their communication skills; oral (speaking and reading), numerical (maths) and visual (graphic and data tables).

It has been suggested by the committee that producing new knowledge includes defining a problem, recording the result from the observation (related to the problem), formulating hypotheses according to the observational results, to test the hypotheses, and according to the collected data accepting, refuting or changing the stated hypothesis. They suggested that teachers should not necessarily follow exactly these ways in lab work because the way of carrying out an experiment depends on the problem stated. However, it is suggested that it would be better if they use these instructions as guidance.

2.2.3.1.3.1 Scientific process skills

Scientific process skills are defined as the basic skills, which helps learning, teaches investigative methods, makes students active, makes pupils develop their responsibility, and during practical activity helps pupils to understand. It is said that these skills are generally used in labs. The skills are divided into three: 'basic processes', 'causal processes', and 'experimental processes'.

1. Basic processes

They are classified as below:

a) *observation*: using their senses to observe the environment,

b) *measurement*: to express the specifications of the materials in a numerical way,

c) *classification*: to classify materials according to their common specifications,

d) *recording the data*: students need to learn that it is necessary to record the data by doing experiments, and this data should be presented by making tables or drawing graphs etc.

2. Casual processes:

These are the cognitive skills, which are used by scientists and the students.

a) *Making predictions*: before doing an experiment students are expected to make predictions about it, for example which variable affects the result most. The teacher should encourage students to ask questions such as 'if you change the volume of water what do you think will happen?' It is suggested that pupils should get into the habit of asking these sorts of questions.

b) *To define the variables*: Defining the factors affecting the problem has a central role in an experiment. It is important to control the variables because this skill is necessary to do a 'fair test'. These are the examples of some questions: what factors make a paper plane fly?, what is the most important variable in testing the solubility of salts?, what is the relationship between pressure and boiling water?

c) *Interpreting the data*: This is about making some interpretations about the data which has been collected, and putting them in groups or tables. It can mean to interpret an observation or a graph. Here are some examples: What does the slope of this graph mean? What does the data show about the relationship between solubility and temperature?

d) *Conclusion*: This is about reaching conclusions from what pupils have done and what they have found out. Students should ask questions such as 'what is my supportive evidence?'

3. Experimental processes:

An experiment is defined as a strong device to confirm or to refute an hypothesis and to have some proof. Doing an experiment includes all the processes above. It is classified as follows.

a) *Formulating a hypothesis*: according to pre-observations, pupils should make temporary generalisation about the problem. They should ask questions such as 'what are the factors for chemical equilibrium?' 'Why does solubility increase sometimes with the temperature and sometimes decrease?'

b) *Using the data*: pupils should present the data by drawing graphs or forming tables etc.

c) *Decision making*: it is about making a statement, or reach a decision by using scientific process skills in asking some questions, for example 'what kind of decision should I make? what might be the possible outcome of this decision?, what are the reasons for my decisions?, which one is the best decision?' There is not enough explanation about this. It might be about deciding and choosing the variables, deciding about the sample or range. Without any explanation it is impossible to follow what they meant.

d) *Changing the variables and controlling the variables*: This means finding out what happens if one of the factors (variables) is changed and the others kept the same. Changing the variables enables students to carry out more experiments and so science becomes more concrete. In order to make the result valid controlling the variables is very important. For example we can keep the mole and the temperature same and then we can examine the relationship between pressure and volume.

e) *Carrying out experiments*: It includes checking the hypothesis and then setting the relationship between variables. The most important factor is for the students to be able to set up the equipment and to understand the aim of the experiment. 'How does ammonium sulphate affect the growth of a plant?' was given as an example of using all the processes. The hypothesis: 'ammonium sulphate has a positive effect on the plant growth'. To test this hypothesis two groups are chosen: the experiment and the control group. For the first group, the rainwater is given to the plants. For the second group the rainwater + ammonium sulphate is used. Temperature and light are kept the same for both groups and observe both results. Here is another example in detail:

Problem:	Rate of reactions: what is the effect of concentration and temperature on the rates of reactions?
Purpose:	Using cognitive skills examining the effect of concentration and temperature on rate of reactions.
Targets:	Student teachers should: a) Understand the effect of concentration and temperature on chemical reaction rate. b) Carry out an experiment, which explains a chemical reaction safely. c) Understand how to use and develop scientific process skills.
Equipment:	For each group 4 100ml flask, 4 25ml measuring cylinder, 2 250ml beaker, 0.02M KIO_3 solution, 0.002M $NaHSO_3$ solution. Bunsen burner, clamp, pure water, test tubes, chronometer.

Method (experiment 1: the effect of concentration)

Measuring:	Measure 25ml KIO_3 and put it into a test tube. Measure 25ml $NaHSO_3$ and put it into a flask and add 1ml starch solution.
Controlling the variables:	Wait for sometime in order to provide thermal equilibrium then add the KIO_3 into the $NaHSO_3$ in the beaker, start chronometer and shake it.
Observation	Observe carefully when you see blue colour and stop chronometer.
Recording:	Record the time.
Prediction:	What is the relationship between concentration and reaction time?

Recording and using data:	Draw the graphs below: a) A graph between the concentration of KIO_3 and reaction time. b) A graph between the concentration of KIO_3 and 1/t.
Hypothesising:	How do you make conclusions about the relationship between concentration and reaction time?

2.2.3.1.3.2 Using laboratories

A. Types of experiments

They start with the types of experiments and accordingly there are three kinds:

1- close-ended: in this method students are given what to find and how to find and what to do, there are instructions, verbally or written. It is suggested that these kind of experiments are for the age 11-14 group and for the pupils who have low abilities.

2- open-ended: students do not know the instructions but the question. The teacher determines which equipment is going to be used. Students do the experiment, record the data, and analyse it. It is suggested that this kind of experiment should be used of secondary schools, universities and for the pupils who have got high ability.

3- discovery method: experiments for testing hypothesis.

Although, open-ended and discovery method are classified as different types, the difference between them is not explained. Even more, unfortunately, there is no example given of each of these types, this makes it more difficult to understand what it is meant.

B. Laboratory approaches

Laboratory approaches (strategies) were also mentioned:

1- deduction method (mostly close-ended): in this method, theory (laws or principles) is given first and then in a lab it is confirmed. It is suggested that teachers should help pupils to believe that the laws and principles are true so that they become more meaningful to them.

2- induction method (mostly open-ended): Students try to find the theory or the law by themselves.

3- discovery method (testing hypothesis) – again here induction and discovery methods are classified as different methods without given any meaningful explanation.

4- technical skills, and **scientific process skills**. Technical and scientific process skills are needed for students to be effective while using the other three approaches. Even though it is not exactly stated in the book, these approaches can be found in Ayas et. al., (1994b).

C. Aims of laboratory work

The aims of using laboratories were summarised below:

1. Since science subjects are complicated and abstract, the aim should be to make pupils understand it better by carrying out experiments,

2. To make student gain skills in working methods, problem solving , observations and generalisations,

3. To develop students' interests towards science.

2.2.4 Recent findings on practical work

Even though the number of research studies on education is increasing, if we compare them to the English literature there is a paucity in this subject. This section, will focus on some empirical research and what the researchers are doing. Mostly the works (at least those which I was able to reach in England) contain ideas and suggestions about curriculum developments (Morgil and Yucel, 1995; Kayaturk et. al., 1995; Morgil et. al., 1995; Ayas et. al, 1993; Akdeniz, 1993; Ayas, 1993; Cepni, 1993; Turgut, 1990), aims and use of lab work (Ertepinar and Geban, 1996, Asici, 1992, Ayas et. al., 1994a and 1994b), difficulties with lab work (Asici, 1992; Akaydin and Soran, 1998;), and safety in the lab (Hamurcu, 1998). All of them agree that science education with practical work is necessary for classical common reasons such as verifying theory better.

Asici (1992) for example, conducted a questionnaire about practical work in biology and distributed them to 100 science teachers. The details of the questionnaire were not given. He found out that the stated problems were lack of equipment and experiments, its unattractiveness of the experiments, the redundancy of existing experiments, and the lack of ability of teachers. Most of the teachers also believed that pupils have to be assessed in their lab performance. He suggested that the science curriculum had to be revised. He also added that a teachers' handbook should have been prepared, in-service teacher training was needed and a new assessment system be arranged to include practical work.

Similar findings have been found in elsewhere (Cepni et. al., 1995, and Akaydin and Soran, 1998). Additionally, the other problems are the time for completing the syllabus, crowded classrooms, the number of children, and university entrance examinations. They had some suggestions for improvements in these areas:

1. Importance should be given to INSET and pre-service teacher training. Also helping student teachers to be more creative in poor situations. They have to have skills so as to produce alternative ways of teaching.
2. The academic calendar should be longer and the number of hours of science classes might be increased to solve the problem of time .
3. Teachers have to be able to choose the teaching methods according to the targets of the subjects.

It is difficult to arrive at a conclusion without enough research on science teaching. It can be said however, that the former curriculum included nothing about procedural ideas. With the NEDP, members of the project are about to (or supposed to) develop the curriculum by preparing materials for teachers, buying lots of equipment in schools and by changing the teacher training programmes. Most of the ideas are not stated where they are coming from. There is a lack of evidence of what it has been mentioned. The suggestions are not based on evidence from teachers' or pupils' understanding.

2.3 Conclusion

The proposals for Turkey can be seen to be an amalgamation of practices already tried out in England. In terms of purpose, the major emphasis is unmistakable: practical work is there to support the development of substantive understanding (either through traditional recipe practicals or those of a 'discovery' nature). In terms of procedural understanding, the focus is on the processes involved.

Although it appears self-evident that an experience of phenomena would enhance the chances of pupils developing an understanding of the science view (substantive understanding), as noted, the evidence from research into children's ideas suggests this is not a simple matter. So far, in this respect, practical work has not been very effective. The process approach to practical work can be questioned on epistemological grounds: do 'processes' exist that can be learned independently of substantive content (Millar and Driver, 1987)? In particular, there is the point that observation is theory-led. One has to know what one is looking for, decide which are the important observation out of all those that could be made. The processes that have been identified are a description of what scientist do, but is this a sufficient specification for a curriculum?

According to Gott and Duggan (1995:39) 'procedural understanding is more than a matter of recalling and using skills and procedures, but rather that it is a set of understanding which are important in their own right'. Its understanding is important not only in first hand practical science but also as a means of effectively examining evidence from other sources. Procedural understanding is the understanding of a set of ideas, which is complementary to substantive understanding but related to the 'knowing how' of science which is concerned with the understanding needed to put science into practice. It is the thinking behind doing the procedures of the scientific enquiry. It is a conceptual content that is concerned with the quality of data. Gott and Duggan (1995) have called these ideas 'concepts of evidence'.

2.4 Statement of the research purposes

As was stated, the recent National Educational Development Project in Turkey was administered with the main purpose of improving the teacher training programme. As part of this project, with guidance of some educators (including some foreigners) and the contribution of some lecturers from Schools of Education, texts were written in each subject. These books are expected to contribute to the efficiency of teaching, with new teaching methods and suggestions. They were not offered as rigid curriculum standards but as resources, and the members of the project stated that they were open to new suggestions.

As discussed, in reviewing one of the books, titled *Chemistry Teaching* (Ayas, Cepni, Johnson and Turgut, 1998), it was obvious to me that the main difference from the former curriculum was the emphasis on practical work. As part of this project, my belief that practical work should be a part of the science curriculum and this has led me to work on this subject. Naturally, my aim is also to make some contributions to the development of science teaching, as I will be a part of this new teacher-training programme.

According to the research findings done in Turkey – though not all of them are based on empirical studies with children or teachers – there are problems regarding lab work in classrooms. According to the findings and according to my experience, I can say that there is a lack of knowledge and understanding about practical work, indicating also, therefore, a lack of adequate training in the teacher education institutions in Turkey. It is believed that if practical work is to really be a part of the Turkish science curriculum, knowing teachers' ideas about this and then developing a strategy for training them, is necessary. Furthermore, teachers' perceptions affect children's understanding. This study therefore aims at gaining an understanding of teachers' perceptions about practical work especially in terms of procedural understanding. This will also give us an understanding of the influence of the curriculum on teachers.

The research participants are not only Turkish teachers. I knew that working with English teachers, who had more experience with practical science activities, would give me a better idea of the relationship between understanding and the curriculum. It was expected that the findings would provide me with some perceptions of teachers' use of practical work; and I believed also that it was important to know the potential difficulties or possible outcomes we might come across. Additionally, having knowledge of the existing understanding of Turkish teachers should help us in taking precautions when we are developing our teaching strategies for student teachers. I hoped that this research would provide guidance to the teacher training institutions and curriculum developers as well as to science teachers themselves.

3 Methodology

This chapter gives a brief overview of the methodology of the research.

3.1 The Research Participants

The research participants, as has already been mentioned, are all science teachers from England and Turkey. The total number of interview participants is 47 – 23 English and 24 Turkish. In England, there were eight participating schools, seven of which are mixed 11-18 comprehensives and one of which is a mixed 11-18 private school. In each school, there were three science teachers, one in each subject area (chemistry, physics and biology). Unfortunately, one of the tapes turned out to be blank. This is why there are 23 English teachers.

In Turkey, there were 10 participating schools, five of which are mixed 11-17 comprehensives, two of which are mixed 11-17 privates, two of which are high-ability (the students are chosen by an examination) 11-17, and one of which is a high-ability 14-17 science-based secondary school. These types cover the range of different schools in Turkey. The schools have no technicians and the average number of labs is two.

In Turkey, it was difficult to convince teachers to be interview participants. The excuse of most was discomfort with the use of a tape recorder during the interviews. Some also said that they were not experienced enough to give information. There is another factor, I believe: that they are not used to this kind of research and most of them believed that the research I was doing would not change anything in this area. Because of the factors stated above, I interviewed whoever volunteered. Interviewing was also limited by time factors, as there was no possibility of making arrangements before my return to Turkey. Data collection was done in a city, which is the third biggest city in Turkey, and the schools reflect the typical specifications of secondary schools in the country.

Below, table 3.1 gives information about the years of teaching experience of teachers in both samples.

Year	No of English Teachers	No of Turkish Teachers
≤5	4	-
6-10	5	7
11-15	4	5
16-20	2	9
21-30	8	3

Table 3.1: The experience of the teachers

In each group, most teachers had more than 10 years experience.

It is the nature that when the number of interviewees is small the results will not show statistical significance (Drever, 1995). However, it is believed that for the purpose of this study, the two samples are sufficient to show the range of thinking about practical work in the two countries.

The two samples were different in a number of ways. The teachers come from different cultures; they speak different languages; they have different backgrounds in terms of teacher training and how they were trained about practical work; the science curriculum has differences; and most of all the systems are different. These differences have effects on the findings of the study.

3.2 Data collection methods

Semi-structured interviews and some non-participant classroom observations were chosen as ways of data collection in this study.

3.2.1 Interviewing

The use of interviews was seen as the best choice of data collection, as the researcher had no knowledge of the practice of teaching science in England. It was anticipated that using a face-to-face interviewing method would result in gaining a more in-depth understanding of the ideas of teachers (Cohen and Manion, 1994, Drever, 1995, and Mertens, 1998). Also, in an interview the researcher can correct any misunderstandings of the questions and can probe for clarification, which is why interviews give high-quality data (Drever, 1995). A questionnaire, for instance, would not give the chance to ask follow-up questions in order to obtain rich data. As a result, the semi-structured interview method –since it is an open situation, having greater flexibility and freedom – was chosen to elicit opinions from teachers about practical work, and the hoped-for outcomes of practical science.

Before conducting the interviews, the researcher and the teachers held an introductory meeting to share information about the purpose and to verify that volunteers did want to participate. It was explained that the purpose of the researcher's study was to gain ideas and opinions about practical work – procedural understanding (in England) – as part of the development of a new Turkish science curriculum. A date and time for the conversation was agreed upon with each teacher, and having gained the interviewee's consent, each interview was recorded and then transcribed for more detailed examination.

In the given references, it was stated that interviewing has advantages and disadvantages. The table below describes the advantages and disadvantages as experienced by the researcher in this study.

Advantages	Disadvantages
• The responses in the interviews could be developed and clarified. Opportunities for response and asking were extensive and probing was possible. This strengthens validity. • The instrument is measuring what we want. • Because of the above, interviews yielded rich materials. • When they knew the researcher, they felt comfortable and spoke freely.	• It was time-consuming in terms of arranging time, travelling, transcribing and analysing. • Because of the above, the size of the sample was small. • Reliability was unknown about how the teachers might respond on another occasion. • English was not the researcher's mother tongue, which sometimes resulted in unanticipated answers with the English teachers.

Table 3.2: Advantages and disadvantages of using interviews in this research

Although a researcher's biases are considered to invalidate the data, that was not, I think, an issue, for as I did not know the actual practice in the schools beforehand, especially in England, no bias showed in data analysis. However, again because of this lack of practice I might miss some things.

The interview guide indicated the questions that had been decided in advance to cover the main points. During the interviews, the researcher used prompts, probes and follow-up questions to get the interviewees to clarify answers. In England, the first analysis was done after interviewing 12 teachers. From the analysis, it was evident that there was not much information about the procedural side of practical work. For the next 11 interviews, therefore, interviewees were prompted to talk more about procedural ideas.

3.2.1.1 Interview questions

The aim is to allow teachers to show their understanding of procedural ideas. However, there were no direct questions such as 'what is fair test', 'what is reliability', or 'what is sampling'. Because I had to be respectful to the teachers in terms of not making them feel that they were being judged. Also, the intention was to see how prominent procedural ideas were in their thinking about practical work. Table 3.3 points out research questions and main interview questions accordingly. The table splits into three because the questions were asked in three progressive stages. This gave three opportunities for the interviewee to volunteer ideas about procedural understanding. Each successive stage was thought now likely to initiate such a response. First, some general questions, especially about the aims of practical work.

Table 3.3: Research and interview questions.

Research questions	Interview questions
What do teachers think about the purpose of practical work?	What is the value of doing practical work? What do students learn from it? And What should students learn from it? Do you find it useful?

Second, there were questions about the types that teachers were aware of.

Research questions	Interview questions
What kind of practical activities are carried out in the science classrooms? Why do teachers use different kinds? Do they emphasise the procedural outcomes of practical work?	What kind of activities do you use and/or prefer? So there are different kinds of practical work – do they have different purposes? When and why do you choose a particular kind? Can you give me some examples? What is the purpose of doing this in such a way?

Finally, the last stage even more probing in order to make the teachers talk about procedural ideas with some shown experiments.

Research questions	Interview questions
Do teachers realise the different outcomes of different types of practical work? Do they emphasise the procedural outcomes of practical activities?	Now I will show you some experiments in your subject and ask some questions about them. What would be the purpose of doing this kind of activity (in terms of procedural understanding)? And how would you carry out this activity to reach these aims? What should kids know or understand after this experiment that they did not know before? What is the key idea of carrying out an experiment like that? Would you use other strategies to teach these ideas, and why? Is one way better than the other?
Teachers' thoughts about the types	Which one of the shown experiments works best in terms of (what they stated for the purpose)?

	What should be the balance, more investigative or not? Why?

There were also questions about the time the teachers spend on carrying out practical work. Finally, the interviews ended with an opportunity to talk about any problems associated with practical work. With these questions, the interviews may identify a set of values that teachers have about the nature of science and the nature of practical work by probing their ideas. They allow us to have their understandings about the subject.

For each group there were similar questions but for the Turkish teachers, because of the differences in the curriculum and in the system, the follow up questions, especially, headed the interviews in a different direction. The interviews began with some close-ended questions, with the aim of gathering some general knowledge. These are:

'*How long have you been teaching and what are you teaching?*', '*Do you use practical activities?*', '*How much time do you spend carrying out practical work in a period of time (in a week or in a term, approximately how many percent)?*'

These kinds of questions give information about their experiences, if they use practical work or not, and the amount of the time they spend by carrying out practical work. (For instance, with Turkish teachers, when asked the second question, most of the time the answer was "*yes... but...*" giving the idea that there are problems at the beginning. Then it was necessary to change the direction with prompting questions such as W*hy?*" or "*What are the difficulties?*").

The experiments shown in the third stage were examples of the four main types of practical work (based on Gott and Duggan, 1995): skill, demonstration, illustration, and investigation. The experiments are shown below.

Table 3.4: Experiments shown during the interviews.

TYPES	PHYSICS	CHEMISTRY	BIOLOGY
SKILL	Connecting up a simple circuit	Using separation techniques	Measuring objects under a microscope
DEMONSTRATION	Radiation from a hot plate	The reaction between sodium and water	Respiration
ILLUSTRATION	Refraction in a glass block	Preparation of copper sulphate from copper oxide	To test for sugar as a glucose
INVESTIGATION	Slope investigations (how speed depends on slope, by rolling a ball down a ramp)	The reaction between marble chips and acid (How does the strength of the acid affect the rate of reaction between limestone and an acid?)	1. The effect of pH on the reaction between pepsin and egg-white suspension 2. To find out how the amount of light affects how fast your seeds grow

The questions for each experiment started with *"What would be the purpose of doing this kind of activity?"* The teachers always began to reply with substantive purposes. With questions such as *"How would you do this experiment?"* or *"What should kids know or understand after this experiment that they did not know before?"* and if necessary asking the purposes in terms of procedural understanding, they were encouraged to talk about their way of doing the experiment, and why they would do it in this way. They were also encouraged to state the learning outcomes and the things that should be understood about the methodology of the experiment. The aim was to get them to talk about procedural ideas. If they said, for example, that, 'The aim is to develop skills', they would be asked follow-up questions such as "W*hat are these skills? Which strategies would you use to teach these skills? What do you expect from kids during the experiment?*" They were also probed with specific questions like "*...pupils will have some data at the end, how can they trust this data, for example... ?*"

After discussing all the experiments, it was asked if any of them were better than the other one and why. They were thus given many chances to talk about procedural ideas. The researcher was very careful not to make teachers feel 'inspected' when asking about their ideas in order to get their understanding. They were always given the last chance to talk by concluding the interview with open-ended questions such as *"Is there anything else that you wanted to tell me?"* and "*Is there anything that I did not cover?*" The teachers spoke freely and often at length.

With the Turkish teachers, the interview schedule was different in some ways. Because of the lack of emphasis on practical work in schools, for example, just showing the experiments was not a useful tool in encouraging discussion, as they did not necessarily realise different types or different outcomes of practical activities or even the existence of procedural understanding. After discussing the purposes of practical work and learning what kinds of activities they use in their lessons, there was an explanatory introductory session. The types of practicals with their different methodologies were explained by giving some examples, as in table 3.4. Then the teachers were asked the purposes of each type, and the reasons why and when they might use a particular one. For example, they would be asked why they might use an investigative activity rather than a demonstrative type. Apart from these discussions, the conversations during the interviews mostly involved the problems they were having.

3.2.2 Classroom Observations

Since "observations can often reveal characteristics of groups or individuals" (Bell, 1993), the use of observation technique would help to identify the teachers' actual practices. Ideally, I would have liked to observe all of the English teachers that were interviewed. However, the reality of school life meant that it was only possible to observe five of the teachers teaching a practical lesson (teachers available for interview were not taking a practical class around that time). These observations were supplemented by visiting the classrooms of other teachers. The number of classroom observations of practical activity is 29 (18 individual teachers). Although it was emphasised that I especially preferred to observe when the teacher carried out an investigative practical, my emphasis seemed to be ignored or they could have different understanding when it is said investigation, as a result, I observed all different types of practical work. The names and the contents of the experiments are given in the next chapter. During the observation, every detail of the practicals was noted. The researcher was interested in the content of teaching during practical work. That is why non-participant observation was preferred. I was, however, a participant of a sort, for I tried to pretend to be a student myself, and checked what kind of knowledge I was given. The points focused on in analysis are stated below:

- type of the practical work;
- the points that teachers emphasised about just procedural understanding.

3.3 Analysing Data

Open-ended interviewing has led me to analyse the data qualitatively. To have relied on a method which yields quantitative data would not have give in-depth and necessary information on teachers' ideas. I was not seeking statistical data.

The qualitative data obtained in response to the open-ended questions were manually analysed by the researcher by categorising the answers. It is realised that there should be an acceptable level of agreement between people as to how to describe data (Cohen and Manion, 1994). That is why 50% of the sample of both English and Turkish teachers were categorised by another Turkish researcher who was doing a PhD in the same area. A high degree of agreement was achieved. First, long statements were compressed into briefer statements in which the main sense of what was said was rephrased in a few words. These were then grouped into simple categories, which made it possible to present the large amount of data in a few tables.

The main data were treated in three sections corresponding to the three stages of the questioning (table 3.3).

- Purpose of practical work
- Types of practical work
- Ideas about the shown experiment

A theoretical model, the concept map of various aspects that should underlie the ideas of procedural understanding was presented as a list (page 48) in the previous chapter. The aspects of this concept map have been used to further categorise the teachers' 'procedural' responses according to the five main areas stated below:

1. **Basic understanding of the fair test:** This includes identifying the variables structure that includes independent variable, dependent variable, and control

variables.

2. **Decisions (need to make trials):** This includes the ranges and intervals of the independent variable and setting of the each control variables (i.e., deciding the amount).
3. **Reliability of data:** This depends on the variation of repeated readings in order to assess; human error; method; instrument which depends on precision and resolution; and other variables which are not or cannot be controlled. In here knowledge and recall of skills are necessary to prevent human error and to decide which instrument to use.
4. **Sampling:** Choosing the appropriate sample.
5. **Presenting data:** Data can be shown by a table, a line graph or a bar chart.

On the basis of Gott and Duggan's (1999) classification of the variable structure in an investigative work, the observed experiments were also classified. It showed some lost opportunities that the teachers could talk about such as the structure of the procedural understanding that could be taught. According to this classification, there are nine types of variable structure. These are identified in the table below:

Table 3.5: Types of variable structure (underlines are independent, italics are dependent variables).

Types of variable structure	**Example**
1. <u>categoric</u> – *categoric*	Finding out <u>which material</u> is *magnetic*.
2. <u>categoric</u> – *ordered*	Does <u>light</u> affect the *growth of a plant*?
3. <u>categoric</u> – *continuous*	Does <u>green light</u> affect the number of *oxygen bubbles*?
4. <u>ordered</u> – *categoric*	Does the <u>amount of exercising (little, a lot)</u> affect *being fit - (yes or no)*?
5. <u>ordered</u> – *ordered*	The <u>amount of exercises</u> affecting the *degree of being fit*.
6. <u>ordered</u> – *continuous*	The <u>amount of exercising</u> affecting the *number of heart beats*.
7. <u>continuous</u> – *categoric*	Does <u>concentration of an acid</u> affect the *amount of gas - (yes or no)*?
8. <u>continuous</u> – *ordered*	Does <u>number of bulbs</u> affect the *brightness* in a series?
9. <u>continuous</u> – *continuous*	Does <u>concentration of an acid</u> affect the *amount of gas* (cm^3)?

This classification will also demonstrate which type the teachers used most. At the same time it will show whether or not importance was given to these structures when experiments were carried out.

3.4 Summary of this research

According to the five main area of procedural understanding, certain aspects are necessary in a scientific process. To find out the perspective of teachers on procedural understanding, this study can be outlined as below.

Box 3.1: Summary of the research based on scientific process

Variable structure	Independent vars: 47 science teachers Control vars: Interview questions Dependent var: Teachers' responses
Reliability of data depends on	1. the researcher 2. interviewing 3. the number of independent vars (sample size).
Sampling →	Science teachers
Presenting data →	In appropriate ways such as in tables.

The chosen independent variables are individual science teachers. Each time they change, the answers change, while the interview questions remain essentially constant. (The interview questions do sometimes change depending on interviewee responses). The reliability of this research of course depends on the researcher, the interview questions, the quality of the interviews, and the size of the sample. In order to get information about procedural understanding in science-classroom practical work, the sample chosen naturally consists of science teachers. Finally, the data is presented. The validity of the research is dependent on all parts of this structure.

3.5 The role of the researcher

Being very new to research in a social science area and having a pure scientist's background, I was a stranger to teaching practice in schools and the research and research methods in education as a social science. This had an effect on me when I began work on this subject and accordingly resulted in some difficulties. That challenged me to make a greater effort to overcome both my problems in the study and also the language problem. (The English participants, however, were very easy to talk with and they spoke at length, giving me much information in addition to my areas of questioning.) Nevertheless, because of the language difficulties, I conducted two pilot interviews in order to gain self-confidence. This also increased my ability to create safe and stimulating interactions and therefore affected the quality of the interviews positively, as Kvale (1996) says. Since there were no difficulties with Turkish participants in terms of language, I was able to show my sincerity and create a comfortable atmosphere for the interviewees more naturally.

Kvale (1996) defines two types of interviewers: a 'miner' or ' a traveller on a journey that leads to tales to be told upon returning home'. As he describes it,

> *'The interviewer-traveller wanders through the landscape and enters into conversations with the people encountered. The traveller explores the many domains of the country. The traveller may also deliberately seek specific sites or topics by following a method, with the original Greek meaning of "a route that leads to the goal"... What the travelling reporter hears and sees is described qualitatively and is reconstructed as stories to be told to the people of the interviewers' own country.'*

I can say that this description reflects me as a researcher in this study.

4 Results

In this chapter the findings of the research will be presented. It will be divided into two parts: data from the research done in England and data from the research done in Turkey. The categories from the interviews, which have been used to structure the responses, and the outcomes of classroom observations will be given.

4.1 Part 1: Data Obtained from English Teachers

4.1.1 Time

According to the responses the categories are defined as below in the table.

Percentage of the total time	No of teachers
<20%	-
20-40%	13
40-60%	7
60-80%	2
>80%	1

Table 4.1: Amount of time that the teachers spend on doing practical work.

The table illustrates the percentage of practical work carried out by teachers. In the right column, the figures represent the number of teachers. As it can be seen, most of the teachers spend between 20-60% of their teaching time doing practical work. One teacher stated the difference between A-level as 20% and the lower school as 25%. The reason for this is the difference between the two syllabuses. Another teacher said teaching time for practical work in lower school it is around 80%. Apart from this there is a consensus that carrying out practical activity depends on the topics taught. Because some topics are all practical like photosynthesis, and some of them such as food chain, animal production, energy transfer are non practical topics. These examples were given by teachers. The key point here is that these teachers are spending a lot of time on practical work. Therefore, it is legitimate to ask why.

The results are going to be presented in three sections which correspond to the three stages of the questioning (as it was mentioned in the previous chapter) with each stage more directly concerned with procedural understanding.

Although the total number of the sample is 23, they are analysed into two parts: first 12 and then the other 11 teachers. With both of them the structure of the interviews are the same but after analysing the first data, for the second group, teachers were probed further to talk about the procedural understanding of the practical work. As it was stated in chapter 3, the reason for this is that it emerged from the first interviews that they are more likely to ignore the questions and tend to talk about more general things such as aims and types of practical work and difficulties that they were having. They did not mentioned procedural ideas and I wanted to give them the opportunity to discuss the ideas if they had any. Overall, they were all given many opportunities to talk about their ideas regarding of procedural understanding during the interviews, purposes and the types of practical work, and examples of experiment were discussed. The results therefore will show if the extra 'encouragement' produced a difference between the two groups.

In group 1, there were four participating schools, all of them are mixed, 11-18 comprehensives. Three teachers for each subject were interviewed from each school. In group 2, there were another four participating schools, three of them are mixed, 11-18 comprehensives, one of which is mixed, 11-18 private. Again three teachers for each subject are interviewed from each school, unfortunately one tape did not record and so was empty, data was collected by interviewing 11 science teachers (3 chemistry, 4 physics, and 4 biology) about their application and understanding of practical activities carried out in their science lessons.

4.1.2 Stage 1

4.1.2.1 Purposes of practical work

As a result of the talk on this aspect there are some categories which came from data just inductively. They all believed that practical work is a good thing, and they explained their own reasons as to why practical work is important. The empirical categories are divided into four. In order of frequency, they are purposes related to substantive ideas, motivation, procedural ideas and communication. The categories are described below:

4.1.2.2 Substantive ideas

The common answer is : 'It helps understanding, reinforces, backs up and illustrates or visualises theory and cements knowledge. The pupils learn things more vividly and clearly if they actually do it themselves then they remember easily. When practical work shows pupils something works then it becomes more real and tangible for them'. This combination of the responses is all about understanding theory like one teacher said '*...it should be aimed at reinforcing something that you covered in a lesson*'. This category is about substantive ideas.

4.1.2.3 Motivation

Another reason that teachers do practical work is that 'it maintains children's interests and helps motivation, when they are bored it is to make them concentrate. Because it breaks up having so much written work and it helps to make pupils more enthusiastic about the subject'. Therefore, the aim of practical work is also to increase one's motivation and to keep them interested. It is believed that 'if the kids can see that the work is fun and it has some relevance to something that is in the real world they can see the point of the lesson, so that they are much more likely to want to learn'. It is also to encourage students to look up things for themselves. This second category highlights the fact that motivation is one of the aims as well.

4.1.2.4 Procedural ideas

Some of the teachers said that practical work helps children to learn and develop their manipulative skills like using instruments or reading graphs. The skills are for instance as teacher no 19 says 'it's to develop manipulative skills, measurement skills. Sometimes to look at a diagram...there is a presentation of the results where they need to be able to put the results in a table'. Although, there is no mentioning about the scientific process I can surely say that this category can be identified as procedural ideas at this stage. However teacher no.1 was the only one giving detailed explanations. S/he said

> '*...to get youngsters to use a complete scientific process that is to identify a question to be tested, to form the question in a way which it can be tested using measurement, to gather evidence by using appropriate equipment, to realise that evidence has to be believable, how often having to repeat measurements, to check their accuracy, to record that evidence and analyse it using appropriate graph work*'.

4.1.2.5 Communication

Finally, the less frequent response is that 'it helps communication between students'. As teacher no.16 says '*apart from learning the skills they also learn how to work together as a team...you need to be able to work with other people, to divide up the jobs that need to be done in the piece of practical so that the whole thing* *comes together as a complete unit'.*

Another reason stated by one teacher is that students should be ready for the examination. For instance, pupils should know how to plot graphs as a practical skill because they need it in the exam.

The ideas mentioned are summarised in the next table: T: teachers, S: substantive ideas, P: procedural ideas, M: motivation, C: communication and teamwork. The table shows us that how many teachers mentioned about which category of the purposes of procedural understanding. For example, 11 teachers said that better conceptual understanding was one of the aims of practical work on the other hand just one teacher saw one of the purposes of practical work was to improve pupils' communication. Total numbers show the number of teachers out of 23.

Table 4.2: Stated purposes of practical work

T	S	P	OTHERS	
			M	C
1	√	√	-	-
2	√	√	-	-
3	√	-	√	-
4	√	-	√	-
5	√	√	√	√
6	√	-	√	-
7	√	-	-	-
8	√	-	-	-
9	√	-	-	-
10	-	-	√	-
11	√	√	-	-
12	√	-	√	-
No of teachers	11	4	6	1
13	√	-	-	-
14	√	-	-	-
15	√	-	√	-
16	-	√	-	√
17	-	-	√	-
18	√	-	√	-
19	√	√	-	-
20	√	-	√	-
21	√	-	-	-
22	√	√	-	-
23	√	-	-	-
No of teachers	9	3	4	1
Total	20	7	10	2

As it can be seen, mention is made about the substantive ideas but far less about the procedural ones. Even in the second group there is no difference. At this stage among the seven teachers in the procedural category, only one teacher actually mentions the scientific process including the reliability issue. It seems that the first thought, in the teachers' mind when asked about practical work is mostly to reinforce the theory. According to the table 4.2 with 20 teachers mentioned substantive understanding and 10 teachers mentioned motivation, this supports what the literature says. On the other hand only 7 teachers out of 23 mentioned procedural ideas.

4.1.3 Stage 2

4.1.3.1 Types

When asked whether there were different types of practicals the answers were diverse. The teachers all knew about the common types or had ideas about them. They named them as demonstrations, illustrations, skill practicals, observation exercises, investigations, class experiments, circuit experiments, supportive practicals, recipe type and reinforcement work. The first five are the types that Gott and Duggan (1995) stated. The others are descriptions of the way practicals are done rather than the types. Table 4.3 gives a brief and basic understanding of how the teachers responded.

Table 4.3: Stated types of practical work.

TYPES	TEACHERS' DESCRIPTIONS
Observation	Students observe and try to explain what they see in terms of their understanding.
Demonstration	Teachers demonstrate when it is not suitable for children to do it.
Illustration	It backs up concepts and illustrates a particular idea.
Skill practicals	It develops manipulative skills such as using equipment properly.
Recipe type	Pupils gain the ability in following instructions and achieving a well-defined outcome.
Investigation	It develops pupils' manipulative and thinking skills.

The categorisation is shown in the box below:

Responses about types of practical work

Categorised into six

1.observation 2.demonstration 3.investigation 4.skill 5.recipe 6.illustraion

Further categorised into five areas

1.fair test 2.decisions 3.reliability 4.sampling 5.presenting

The teachers claim that they use different types from time to time. For instance, demonstrations are used by teachers when an experiment is not feasible for students to do themselves e.g. with very complex equipment when safety is called into question, or when resources and the time are limited. Also teachers demonstrate, to show how to do an experiment before pupils do it themselves-especially for low ability groups, and also to sum up an experiment. Another advantage of demonstrations is that the teachers can ask pertinent questions. Demonstrating can also be done very quickly. There is another reason why teachers use demonstrations, if the pupils have had a lot pressure due to the volume of work in the previous few weeks, demonstrations (being less taxing) can ease this pressure. Demonstrations were the most favoured type of practical work for some reasons. Similarly, the 1918 report also suggested to use demonstrations, becuse they considered that individual practical work was time consuming and not economical.

Now among the others, invetigative type will be the focus since it is the type most likely to elicit ideas to do with procedural understanding.

4.1.3.2 Investigation

Some of the ideas about investigations are not different from the responses regarding the purposes of practical work such as reinforcing theory or gaining manipulative skills. On the other hand some of the teachers, started to emphasise different points in terms of procedural understanding. In order to be more specific, certain aspects have been used to categorise the responses based on a theoretical model. This is the concept map of various aspects that should underlie the ideas of procedural understanding (Gott and Johnson, 1999) which was given in chapter 3. The frequency of the teachers' statements in these areas is presented in the table below.

Table 4.4: Teachers' ideas about procedural knowledge in investigative work.

Teachers	Fair test	Decisions	Reliability	Sampling	Presenting
1	√	√	√	-	√
2	√	-	-	-	-
3	-	√	-	-	-
4	-	-	-	-	√
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-
10	√	-	-	-	-
11	-	-	-	-	-
12	√	√	-	-	-
Number of teachers	4	3	1	0	2
13	√	-	-	-	-
14	√	-	√	-	-
15	-	-	-	-	-
16	-	-	-	-	√
17	-	-	-	-	-
18	-	-	√	-	√
19	-	-	-	-	-
20	√	√	√	-	√
21	-	-	-	-	-
22	√	-	-	-	-
23	-	-	-	-	-
Number of teachers	4	1	3	0	3
Total	8	4	4	0	5

The table illustrates the frequency of the emphasised points in the area of procedural understanding while the teachers were talking about investigations. In the second group the teachers were expected to talk more about procedural ideas but it can be deduced from the table that there is not much difference between the two groups. Overall the number of ticks are low, only 12 teachers mentioned this area specifically. Naturally, the quality of the responses, which will give us an overview of the teachers' understanding, is different; for instance there are ticks in the second column, even though we do not expect to see identical responses. In relation to the table some of the responses are going to be illustrated to show the quality of the responses. For example, eight teachers mentioned about fair test but it does not mean that they all say the same thing. That is why some of the teachers are given as an example. This will also explain, how the tables were created.

Teacher no 1 explained what s/he meant by giving an example of 'dissolving jelly in hot water' s/he said '*...first of all to decide which variables affect the speed of jelly to dissolve...type of jelly, size of jelly, temperature of water. They're then given the freedom...to decide which are those variables...*'. On the other hand teacher 22 said '*...get them to think about things they could investigate and make a fair test*'. Another explanation (teacher 14) is that "*it is to develop skills like looking for variables, fixing on variables, to make it a fair test* (category 1)... *they have to look at the accuracy by asking 'is that correct', 'is that valid'* " (category 3).

Teacher 18 explained the way of doing investigative work as '*giving pupils the instruction on planing, obtaining evidence, using reasonable precision and skills, analysing the evidence – how good they think the evidence* is (questioning if it is believable)-, *presenting results in a way that explains something –e.g. drawing line graphs-, evaluating methods and results – how well they think they did it…maybe this piece of equipment was giving me a wrong reading and it affected results'.*

Teacher no.12 defined investigation as "*they plan what they're going to investigate, look at variables, make decisions what they are going to control, what they are not going to control, what they need, what they don't and they make decisions about what they are measuring, what they are doing and do all themselves and that would then be called an investigation*".

Teacher 16 for example had negative ideas about investigative work and just mentioned the last category. S/he said "*in an investigation setting out work and how to record results and what to do with results. You get that just by doing practical work not making it an investigation. I think you are really re-inventing the wheel a lot of the time so I am not a big fan of investigations*".

So what was the emphasis on? Apart from the fair test idea and presenting data, decisions and reliability issues make the investigations different from the other types discussed. If we look at just those areas, out of six there are four teachers in the aspect of decisions, and four teachers in the aspects of reliability. And two of them mentioned both, for instance teacher 1 said '*…to gather evidence by using appropriate instruments to take the evidence to realise that evidence has to be believable so to repeat measurements to check their accuracy…*'. Teacher 20's expression was similar '*you get them to think –oh well maybe we did not do that* *right- do you think that's accurate and you'd be encouraging them to take repeat readings*'.

So the teachers have some incomplete ideas, about some points like the range or interval of the independent variable or how it should be done accurately. In the fair test for example there is no example or expression given about the types of variables.

According to the teachers who did say anything about the five areas, they said that general understanding of investigative work is to make pupils to solve problems, to give them responsibility to do something on their own (which is confusion with discovery work), and to attain the highest marks for the course work which is a part of the syllabus.

So far at the end of stage two, we have some ideas about the purposes and about investigative work. The table below illustrates the association between the two stages. It shows the number of teachers who talk about procedural ideas in both stages and it also summarises the relation between table 4.2 and 4.4.

Table 4.5: A comparison between responses of stage 1 and 2.

	For investigation	
For purposes	yes	No
Yes	**4**	**3**
No	**8**	**8**

According to the table 4.5, four teachers are consistent by mentioning the ideas, and 8 teachers are also consistent by not mentioning the ideas. The table also showed that being focused on investigation did draw more responses on procedural ideas with the figure 8 in the second column, although 3 did not mention, when they had previously. This figure 3 seems strange in the third column. It was expected that there should not be a yes-no combination. However, knowing that these three teachers only mentioned manipulative skills, drawing and reading graphs, or presenting results in an appropriate way, it is not that surprising. In the investigative aspects, the five areas include more than just manipulative skills. On the other hand, the figure 8 in the second column shows that giving a second opportunity for teachers to talk had the effect of encouraging some of them to remember and discuss these issues.

4.1.4 Stage 3

4.1.4.1 Experiments

This (stage 3) was another chance for them to talk more specifically about procedural ideas. In this section, teachers' ideas of procedural understanding are going to be presented. Firstly, the frequency of the responses in terms of substantive and procedural ideas, in each example in a table will be shown. There were again responses about both substantive and procedural ideas. When they talk about the aims of the experiments for example, they were mentioning to learn about theory better. That is why that kind of responses are categorised as substantive ideas in the table below (N1 is the number of teacher in the first group and N2 is the number of teachers in the second group).

Table 4.6: Emphasised points of shown experiments.

T	Skills		Demonstration		Illustration		Investigation	
	S	***P***	*S*	***P***	*S*	***P***	*S*	***P***
1	√	√	√	-	√	-	√	√
2	√	√	√	-	√	-	√	√
3	√	-	√	-	√	-	√	√
4	√	-	√	-	√	-	√	-
5	√	-	√	-	√	-	-	-
6	√	-	√	-	-	-	√	√
7	√	-	√	-	√	-	√	√
8	-	-	√	-	√	-	√	-
9		√	-	-	√	√	√	√
10	√	-	-	-	-	-	√	√
11	√	-	√	-	√	-	√	√
12	-	-	√	-	√	-	-	√
N1	9	√	10	-	10	1	10	9
13	√	√	√	-	√	√	√	√
14	-	√	√	-	√	-	√	√
15	√	√	√	-	-	√	√	√
16	-	√	√	√	√	√	-	-
17	√	-	√	-	√	√	√	√
18	√	√	√	√	√	√	-	√
19	-	-	√	-	√	√	-	-
20	-	-	-	-	-	√	-	√
21	-	√	-	-	√	-	-	-
22	-	√	-	-	√	√	√	-
23	√	√	-	-	√	-	√	√
N2	5	8	7	2	9	8	6	7
total	14	11	17	2	19	9	16	16

The table shows the experiments, (-especially when talking about the key ideas and purposes of the experiments and the things pupils should gain from them) and how often teachers talked about the procedural ideas of the experiment. It shows the balance between substantive and procedural understanding. The quality of the responses will be explained later. As we can see they have a tendency to talk a lot about the substantive ideas except investigations. It also shows that they did give emphasis to procedural understanding. In the other experiments it was not too different from what they said previously in terms of substantive ideas. More importantly however are the areas of procedural understanding (of the experiments) the teachers mentioned. Overall we can also see that with the second group there are more ticks in the 'P' columns as they were more probed (but not for investigations).

4.1.4.1.1 Skill

The experiments in this group are: Using separation techniques (chemistry), connecting up a simple circuit (physics), measuring objects under a microscope (biology). Some of the teachers emphasised that the outcome of these experiments should be to develop skills, for example, using a dropper, separating funnel, filtering or using a microscope, or connecting a circuit up. Teachers agreed that pupils should know these kind of skills for future experience, for instance, investigative work which is assessed by the syllabus. According to Gott's and Duggan's (1995) procedural taxonomy, these skills can be put under the *knowledge and recall of skills* knowing how to use the equipment which is important for getting accurate results. Its importance was only mentioned by two teachers (9 and 13), that pupils should be trained, as they are developing skills, in terms of being accurate.

4.1.4.1.2 Demonstration

The examples of experiments in this category are: the reaction of sodium with water, radiation from a hot plate and respiration. In this group, as it can be seen in the table, apart from two teachers (16 and 18) there is no tick under this category. One of them, again being manupilative skills like reading a thermometer and plotting cooling curves for the radiation experiment. The second one is about a fair test -for the same experiment again. The teacher said that '*it is only fair that if both surfaces are the same distance*'. So the teachers do not see demonstration as a chance to talk about procedural ideas. They do not mention the quality of the data.

4.1.4.1.3 Illustration

The experiments shown are preparation of copper sulphate from copper oxide, refraction in a glass block, and a test for sugar as glucose. In this group again the teachers once again mentioned mostly manipulative skills like using instruments, drawing diagrams, and plotting graphs. Accuracy is a point also mentioned by three of them (17, 18, 19): '*pupils should be making accurate points, they should be able to make good measurements*'. As, for refraction '*they should measure the angles correctly*'. Teacher 9 mentioned range: '*...we extend it to estimate the sensitivity of* *benedict test. pupils can make a series of dilutions of glucose from 10 down to 0.1% and test them by using the standard benedict method and looking for the color changes*'. Teacher 20 talked about the possibility of pupils answering an investigative question: '*this leaf has been kept in the dark, this one has no carbon dioxide, this one is green and white; how can you prove what conditions are needed for photosynthesis?*' (variables).

Although in the table there are ticks for procedural understanding for each category, the content of them might be different especially for the investigations. The content of the procedural understanding of the investigative type of experiments will be given in a different table such as table 4.4 which was given before.

4.1.4.1.4 Investigation

The experiments are the reaction between marble clips and acid, slope investigations, and the effect of pH on the reaction between pepsin and egg-white suspension or finding out how the amount of light affects fast seed growth? With these experiments they were actually given a third chance to explain their knowledge.

The results are presented in the table below. It will show the frequency of the teachers' emphasis in the area of procedural understanding in the five areas. It should be noted however, that the sampling issue is mostly appropriate for biology experiments.

Table 4.7: Emphasised areas of shown investigative experiment.

Teachers	Fair test	Decisions	Reliability	Sampling	Presenting
1	√	√	√	-	
2	√	-	-	-	-
3	√	-	-	-	-
4	-	-	-	-	-
5	-	-	-	-	-
6	-	√	√	-	√
7	-	√	√	-	√
8	-	-	-	-	-
9	√	-	-	-	-
10	-	√	-	-	-
11	√	-	-	-	-
12	√	√	-	-	-
Number of teachers	6	5	3	0	2
13	√	√	√	-	√
14	-	-	-	-	-
15	√	-	-	-	-
16	-	-	-	-	-
17	√	-	-	-	-
18	√	√	√	-	√
19	-	-	-	-	-
20	√	√	√	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	√	√	-	-	-
Number of teachers	6	4	3	0	2
Total	12	9	6	0	4

Even though the second group of teachers were probed to talk further there is not much increase of the number of the teachers. First it would be useful to see the association between the table 4.4 and table 4.7 as it summarises the third opportunity. This table shows that 'three stage design' seems to be working for some teachers.

Table 4.8: A Comparison between stage 2 and 3.

	For showed experiment	
For investigation	Yes	No
Yes	**8**	**4**
No	7	**4**

Compared with the second stage, at this stage, however, 7 teachers started to mention procedural ideas. On the other hand four of them did not say anything although they have ticks in table 4.4 (teachers 4 and 16 presenting, teacher 14 fair test and reliability, and teacher 22 fair test). Why did some mention procedural ideas for the first time but not the second time? For example, the first time, teachers four and 16 said "*It is about presenting results*". Again, the first time teacher 14 had some ideas about variables and accuracy but apparently could not apply her/his knowledge. And teacher 22 gave an explanation without getting into details, by saying, "*get them to work in groups and think about things they could investigate and make a fair test*". They did not seeem to use their understanding; or perhaps they felt that the second time, they did not need to explain what they had said before. However, the teachers who said nothing made great emphasis on substantive ideas. Again the data supports that they either do not have the knowledge underlying procedural understanding or they do not seem to apply their existing knowledge to concrete situations. On the other hand 15 teachers in total mentioned some procedural ideas. The fair testing is dominant area. These results are similar to the ones found by Watson et. al. (1999). This was done by conducting a questionnaire with over 1000 teachers. It seems that fair testing idea is widely known by teachers.

Most of the teachers talk about variables and then decisions. Regarding the fair test idea for instance, teacher 2 said '*...temperature might have an affect and the concentration might have an affect, the size of the particles may have an affect...*'. Similarly, teacher 3 did not actually mention so many things by saying '*this tends to be done as an investigation because of the variables-temperature, concentration and surface area*'. The other responses in this area are not much more different than these two. It was like '*they have to learn a fair test*' (teacher 11) or '*they have to choose one of the possible variables*' (teacher 15). On the other hand there are some responses explaining it very well, and this is presented next.

If we again look at the areas of decisions and reliability, nine of the teachers mentioned decisions, six of them mentioned reliability, of then six mentioned both. Teacher 1 stated that '*...probably a trial one first and in the trial one look at the other control variables like the concentration of the acid, volume of the acid. They will be responsible for their own decisions as to what amounts, concentrations, temperature are. Then they have to work probably two hours of work to get reliable result*'. It seems that this teacher has got the idea of investigative work from the beginning with her/his consisted responses.

Some teachers produced the same responses, for instance teachers 6 and 7. They mentioned range, repeatings, accuracy and obtaining reliable evidence. '*...you'll be looking for accuracy and precision as to how they measure the speed. You've got a range of different levels. You'd hope that they would do many repeats and averages...within a repeat table they can also make evaluations as to how reliable the evidence is*'.

It seems that the teachers who responded have some ideas when they see concrete examples with the terms but without reasons. They did not say much about why they consider these issues important.

4.1.5 Preferences of the Teachers – Their Actual Practice

Demonstrations and recipe type practicals are the most favourite ones. On the other hand, even though their actual practice is demonstration and recipe type dominant they do not seem to forget the fact that investigative work is part of the curriculum and is compulsory. That is why they feel obliged to use investigations. Later, the data from the classroom observations will present the results about teachers' actual practices.

4.1.6 What is the Teachers' Observation about Pupils' Reaction?

The common observation of pupils' reaction is that they like it very much.

Due to the fact that it is very interesting and favourable to do practicals where it has more visual things like chromatography, pupils would also like to see instant results. Another reason why they like practicals is that for pupils it means that they can move around and they are allowed to do things. According to another observation some pupils tend not to take it seriously in terms of learning but they regard it as play. There are some observations suggesting that some pupils do not like practicals because of the formal piece of equipment such as ones used in distillation. Pupils seem to be bored with the equipment. And finally some pupils do not appear to see the point of it and at the end of the experiment they say "so what?"

Some teachers classified pupils' reactions according to their ability level, or according to the type of practicals being done. For example, *if they are more able students*; they like to do practicals like investigations because it gives them a chance to put their knowledge into practice. *In the case of low ability* students; they are not interested in science and they do not want to do practical work. They do like certain types of experiments though for instance, d*emonstration*; 'they love demonstrations that flash and bangs in especially the younger ones'. *Investigations* are the least favourite for some of them; teachers observed that they prefer short-term things, like blowing into limewater. They find it very difficult to cope with and 'it has a down side for them because it involves a lot of writing'. On the other hand according to some teachers, some pupils like investigations especially the more-able ones for the reason stated above and because they like to do things themselves.

4.1.7 Classroom Observations

The classroom observations were made in order to find out the teachers' actual practices in the classrooms. Two teachers were observed five times, three teachers for two practicals each, 13 teachers for one practical (so altogether 18 teachers were observed). Some details about the experiments are given below.

1. Respiration and Breathing: Pupils, working individually, breathed on lime water to prove carbon dioxide and on the window to prove water. (Student demonstration).
2. Photosynthesis: Investigating how the colour of lights affects photosynthesis.
3. Water Movements: With the instruction sheet, pupils, working in groups of 2, 3, and 4, did three experiments as a circus activity. The experiments showed the passage of water through the xylem – observing a plant in a jar of water containing a coloured dye; observing transpiration – of two potted plants with a polyethene bag tied round the base of the stem (one of them is cut at the base of the stem); and finally, finding out how much water a plant loses and gains – a plant in a measuring cylinder full of water with a thin layer of oil, comparing the weigh before and after 24 hours to see the difference. Teacher called this investigative work but it is done by following a recipe.
4. How seeds grow: An investigative activity about how heat, light and moisture affect seed growth.
5. Fertilizers: An experiment investigating the amount of lime needed to neutralise Moorland Soil.

6. Solar system, gravity, and magnetism: Pupils produce a simple electromagnet using nail, wire and a power supply, working in groups of 2 or 3. They observed the magnetic field by magnetising small nails, also changed the voltage and noted the difference. The activity followed a recipe.
7. Magnetism: The teacher demonstrated magnetic and non-magnetic materials.
8. Magnetism (making magnets): This was a teacher demonstration showing how to magnetise some pins using a magnet.
9. Making electromagnets and strength of electromegnets: Pupils made a coil, and by using different materials and changing the number of turns, they tried to find out which coil was the strongest. Investigative but using an instruction sheet.
10. Electromagnets, taking turns: This was an investigation to see if the number of turns in a coil affects the magnetism it causes.
11. Magnetism: This experiment was about identifying hidden magnets in some boxes and drawing a map to show the shape of the magnets in the boxes.
12. The series circuits: Pupils made circuits following an instruction sheet and observed the differences in brightness. Illustrative and investigative.
13. Resistance of a wire: Finding the resistance of a wire by changing the voltage then recording the current. Illustrative.
14. Making a kettle: Pupils measured the temperature of different volumes of water which had a wire connected to a power supply. Illustrative.
15. Investigating how a weight stretches a spring: This involved adding weight to the spring and then measuring the extension each time in order to observe Hooke's law.
16. Best conductor of heat: This experiment involved heating some metals that had a

pin attached at the end with wax. They measure the time taken for the wax to melt and the pin to drop.

17. Expansion and contraction: A teacher demonstration to show metals conduct heat and expand when heated.
18. Magnetism – mystery boxes: Using iron fillings and compass, pupils tried to find out what type of magnet is in the box.
19. Magnetism: Pupils identified magnetic and non-magnetic materials by observing.
20. Distillation: The teacher demonstrated the distillation of water from a solution.
21. Burning fuels: Working groups of two pupils heated some water in a beaker using a bunsen burner, in order to prove that the condensation outside the beaker was because of the gas burned.
22. Preparation of aspirin: Working individually, the pupils prepared a sample of aspirin by following an instruction sheet.
23. Marble clips and acid: Investigating the effect of the concentration of the acid on the reaction between marble chips and acid by measuring the amount of gas emitted and the time.
24. Displacement reactions: A teacher demonstration showing the reactions of some metals with some solutions to demonstrate participating and the reactivity of metals.
25. Dissolving: The pupils tried to find out which solvent dissolves which solute.
26. Separating liquids: The teacher demonstrated miscible and immiscible liquids.
27. Solubility: To find out at which temperature how much KNO_3 can dissolve in water. Pupils followed a recipe. Each group used different amount of KNO_3.
28. Separations and solubility: With given instructions, pupils separated a mixture of

sand and salt.

29. Chromatography: Pupils created a spot at the centre of a filter paper by using a felt-tipped pen. They used water as a solvent.

How these are grouped by teachers e.g. which are the observations with the same teacher, is shown in the table below:

Table 4.9: Numbers of observations grouped by teachers.

Teachers	Observation numbers
A	2, 10, 14, 22, 23
B	7, 8, 12, 18 19, 27
C	3, 4
D	25, 26
E	28, 29

4.1.7.1 Emphasised points during the actual practicals

As a result of the observations, a table is constructed below which explains which areas the teachers emphasised during the practicals.

Table 4.10: Emphasised areas during the classroom observations.

No. of obs.	Fair test	Decision	Reliability	Sampling	Presenting
1.Respiration and breathing	-	-	-	-	-
2.Photosynthesis	√	-	-	-	-
3.Water movements	√	-	-	-	-
4.How seeds grow	√	-	-	-	-
5.Fertilisers	-	-	-	√	√
6.Solar system and gravity	-	-	-	-	-
7.Magnetism	-	-	-	-	√
8.Magnetism	-	-	-	-	-
9.Strength of electromagnets	√	√	-	-	√
10.Electromagnets	√	√	-	-	-
11.Magnetism	-	-	-	-	-
12.The series circuits	-	-	-	-	√
13.Resistance of a wire	-	-	-	-	-
14.Making a kettle	√	√	-	-	-
15.Stretching a spring	-	-	√	-	√
16.Best conductor of heat	√	-	-	-	√
17.Expansion and contraction	-	-	-	-	-
18.Magnetism	-	-	-	-	-
19.Magnetism	-	-	-	-	-
20.Distillation	-	-	-	-	-
21.Burning fuels	-	-	-	-	-
22.Aspirin	-	-	-	-	-
23.Marble clips	√	√	-	-	√
24.Displacement reactions	-	-	-	-	-
25.Dissolving	-	-	-	-	√
26.Separating liquids	-	-	-	-	-
27.Solubility	-	-	-	-	√
28.Separations and solubility	-	-	-	-	-
29.Chromatography	-	-	-	-	-
Total	8	4	1	1	9

I had a chance to observe some teachers who had been interviewed. For example, at the second stage, teacher no: 18 did mention about fair test, decisions, reliability and presenting data, basically by saying, *"They have the skills of setting up a result table, making a fair test. Then they can look at those measurements and things they have done to see whether they are good enough which depends on the measurements they've taken and they have to plot graphs... "* However, when s/he was doing the experiment of 'resistance of a wire-no: 13,' these categories were never mentioned although the experiment was suitable for the investigative work. So there is inconsistency between what they said and what they did.

Another example came from teacher no: 17. S/he said during the interview that, *"They keep everything the same and roll the toy car down,"* and that it was about a fair test idea. Again during the observation, s/he gave the information about variable structure, fair test and told pupils to present the data in a table. S/he was consistant.

Teacher no: 8, on the other hand, did not say anything about these areas during the interviews nor during the actual lesson either. The table below illustrate these clearly.

Table 4.11: Combination of table 4.7 and 4.10 for the teachers both interviewed and observed. (F: Fair test, D: Decisions, R: Reliability of data, P: Presenting data).

Teachers no.	Observation no.	Investigation	Observation
4	1	-	-
8	7, 8, 18, 19, 27	-	P
9	12	F	P
17	16	F	F, P
18	13	F, D, R, P	-

4.1.7.2 Types of practical work

We can make another table concerning the nine types of variable structure (Gott and Duggan, 1999). This table explains the types of variables which were observed. in the practicals:

Table 4.12: Variable types in the observed practicals.

Types of variable structure	Experiments
1. categoric – categoric	3, 7, 19, 24, 25
2. categoric – ordered	4
3. categoric – continuous	2, 16
7. continuous – categoric	5, 10
8. continuous – ordered	12
9. continuous – continuous	6, 9, 10, 12, 13, 14, 15, 23, 27

Most of them have type-9 structure which provides stronger data. They did not discuss which type of variable structure they were going to use. Almost all of them instructed verbally or in writing. Some of the examples from each type are presented below, including investigative types. The examples of observations gives more idea about the practice and also shows lost opportunities that more procedural ideas could have been mentioned. They also show the procedural ideas were/could have been addressed by the teacher. The practicals were carried out were mostly the traditional type of practicals, mostly teacher directed. There is not enough emphasis on the five areas of procedural understanding. The teachers' roles were to walk around or answer when pupils ask questions about what to do. There was no example of pupils describing the questions to be investigated themselves, nor any examples of pupils chosing the range. They did not go beyond setting up a fair test.

4.1.7.2.1 Type 1, categoric – categoric

7. Magnetism (Y7) : It was a teacher demonstration. The teacher demonstrated magnetic and non-magnetic materials to the pupils by using zinc, plastic, wax, acrylic, aluminium and lead as categoric independent variables. Then 'magnetic' or 'non-magnetic' became dependent categoric variables. There was no emphasis on the variables; it was explained simply as *"These are the materials and we'll see if they are magnetic or not."* At the end of the experiment, the teacher wanted pupils to draw a table with conclusions. There was no table given to them. Pupils could have done this experiment by themselves rather than watching what the teacher did, experiencing each material by touching. Also, while using this kind of experiment, definitions of the variable can be given so that pupils can learn them in use.

4.1.7.2.2 Type 2, categoric - ordered

4. How do seeds grow (Y8)? This was an investigative work. The teacher encouraged pupils to find out the variables and the structure by asking questions such as, "How do seeds grow?" and "What are the variables and how do they affect seed growth?" The independent categoric variables were light (dark and light), heat (cold and warm) and moisture (wet and dry). The dependent ordered variable was the growth of seeds (e.g. 'It looks more lively than this'). The teacher also said "We should keep everything the same and only change one thing because of the fair test." Then students had to make plans about the variable structure and work it out. There was emphasis on deciding the variables but not on their types, and not on the other issues like range of the independent variables, the reliability or the sampling (number of seeds and the type of seeds).

4.1.7.2.3 Type 3, categoric – continuous

2. Photosynthesis (Y10): Pupils observed oxygen bubbles (continuous dependent variable) during photosynthesis by putting a plant into a beaker full of water including sodium bicarbonate, covered with a funnel under a light of different-coloured bulbs (green and yellow-categoric independent variables). Each group used just one coloured bulb then their results with the others. The equipment was set up ready for the pupils and they did not make any decisions. The teacher checked the results during the practical. In this way of doing it, the pupils only observed the bubbles and presented what they saw in a table, whereas the whole process of procedural knowledge could be used. The pupils could use both coloured bulbs instead of using just one colour so that to see the difference and to make it fair by emphasising the same conditions for both experience. Then they could repeat the counting oxygen bubles for the experiment to be reliable.

16. Conductors (Y10): The purpose was to investigate which metal is the best conductor of heat. The pupils were told to write their own design based on some information about the variable structure given by the teacher. The categoric independent variables were aluminium, brass, copper and steel. The teacher also mentioned about fair test, which involved keeping the strengths and the thicknesses of the metals the same. The pupils heated the metals, which had a pin attached with wax at the end. When they heated, they measured the time (continuous dependent variable) until the pin dropped. At the end, they presented the data in a table. Again, even though the teacher mentioned fair test and the variable structure the other procedural ideas were not the issue such as reliability (using the same amount of wax etc.).

4.1.7.2.4 Type 7, continuous – categoric

5. Fertilizers (Y10): Using instructions written on the board, the pupils investigated how much lime was needed to neutralise Moorland Soil. They mixed a fixed amount of the sample with different amounts of lime (continuous independent variable) and observed the colours of the mixtures by an indicator (categoric dependent variables). They made a table from the results. The teacher told pupils why they were using Moorland Soil (because it has an acidic structure). This was the only activity in which sampling was mentioned. However the teacher did not place emphasis neither on this issue nor on the others such as using sensible range and intervals of the independent variable or fair test or reliability.

4.1.7.2.5 Type 8, continuous – ordered

12. Series Circuits (Y7): By looking at the circuit diagrams on the given sheet, pupils set up the circuits and wrote their observations. The table on the sheet included circuit diagrams, number of cells, number of bulbs, brightness in words and brightness in numbers. Because these decisions were made for the pupils, it was not really an investigation. In this activity, the number of cells and number of bulbs were the continuous independent variables, and brightness in words (dimmer and dimmest or brighter and brightest) was the ordered dependent variable. This is also an example of continuous – continuous type, when finding brightness in numbers. However, no emphasis was given to the variable structure.

4.1.7.2.6 Type 9, continuous – continuous

10. Electromagnets, taking turns (Y11): This was again done following an instruction sheet. Pupils made a simple coil and checked the number of paper clips (continuous dependent variable) the coil could pick up by changing the number of turns and the voltage (continuous independent variables) in the coil. They did this using an instruction sheet which guided them. There was no discussion about the nature of investigative work. Students were on their own, possibly making mistakes. For instance, they used the same paper clips for each independent variable, which probably misled them because they were ignoring the idea that the paper clips were thus already magnetised. So validity and fairness of the experiment was of course questionable. The instruction sheet included the direction that pupils could change the number of coils, as well as some questions like "What factors can you vary in your investigation?"

15. Investigating how a weight stretches a spring (Y8): Although the teacher said this is an investigative study, pupils used a recipe given to them with'do this and do that' instructions. They added various weights (continuous independent) to the spring and measured the extension (continuous dependent). After making a table, they drew a graph of extension against load for the spring. The teacher only mentioned accuracy about measuring the extension correctly. In order to do this, they fixed a pin to the hanger so that they could read it more accurately.

23. Marble chips and acid (Y10): The teacher gave 1M and 2M HCl. Then students investigated the effect of the concentration of the acid (continuous independent variable) on the reaction between marble chips and acid by measuring the amount of gas (continuous dependent variable) produced and the time (dependent variable). They presented the results by making a table and then drawing a graph. The teacher emphasised that in an investigation, they have to do some trial experiments and have a number of readings. For this experiment, the teacher said that they had to use the same size of marble chips.

27. Solubility(Y8): The purpose was to find out the solubility of potassium nitrate. The pupils followed a recipe. They wrote down the temperature (dependent variable) at which the solid just dissolves, using different amount of potassium nitrate (independent variable). Each group weighed out a different amount. At the end of the experiment, they made a table and drew a line graph. There were no decisions made by the children. There was no emphasis on the importance of the variables or range, nor anything about procedural ideas either.

4.2 Part 2: Data Obtained from Turkish Teachers

In this part, the data which was obtained from the interviews with Turkish teachers will be presented. There were 24 participant science teachers from 10 schools, which were chosen randomly. For some reason, it was really difficult for the researcher to convince them to talk and to explain what it was about. That is why whoever wanted to talk was accepted. The interview questions are explained in the methodology chapter, but the data from them is quite different from that of the English teachers, because the two systems are structured differently. The main difference about practical work mostly stems from the assessment system. In Turkey, pupils are not assessed about the knowledge and understanding of procedural ideas, but only about theory. All of the teachers agreed that they should use practical work but because of reasons like the university entrance examination, they stated that they could not find a suitable environment. Accordingly, the teachers tended to talk mostly about problems which they were having, as well as giving some suggestions at the end. I shall now present the essence of the data, beginning with the time they spent on doing practical work.

4.2.1 Time

Percentage of the total time	No of teachers
<20%	16
20-40%	7
45%	1

Table 4.13: Amount of time teachers spend on doing Practical work.

In the table it can be seen approximately what percentage of the total time the teachers used for practical work. Most of the time was used in teaching theory. This is very different from England.

4.2.2 The purpose of practical work

The teachers' responses regarding the reasons for 'why practical work?' are familiar and their answers can be categorised into three main groups: learning better, motivation, and developing practical skills.

1. Learning better

This is the most –mentioned category. All of the teachers agreed that some practical work helps students understand the concepts better so that the lesson will be fruitful, since they are learning the theory by experiencing and by doing themselves, using techniques like touching, watching, or smelling. Students need to use all their senses when learning science, so that they can remember more easily.

2. Motivation

Practical work also makes students more interested in and curious about science, leading to a love of science. It gives students an opportunity to think and create, and shows them they can actually do something by themselves. It encourages them to do something. Although, according to the table 4.13 they hardly use practical work, it seems a contradiction this is what the teachers think.

3. Developing practical skills

With practical work, pupils gain some basic skills like using equipment, and knowing about materials and equipment.

Apart from these three reasons, the other purposes are as follows:

1. Practical work teaches students how a scientist works and thinks.
2. It improves their friendships: they learn how to discuss, how to share and how a team works.
3. With practical work, pupils can see what is going on in daily life and relate the science knowledge to this.
4. It helps to discover students' abilities in science.

There are also tautological explanations like, "because science lessons should be visual" or "because the research says that it has a positive effect on learning". They do not really question the research; does it really motivate learning?

4.2.3 Practices of the teachers

It is important to know what kind of activities the teachers use in order to find out what knowledge they have about practical work. Mostly, if they used practical work, they preferred teachers' demonstrations and recipe-type ones. Role-play was another choice, and they also believed that giving examples from daily life was a way for teachers to be helpful instead of doing practical activities. The teachers who did not use practical work at all, unfortunately had no idea what kinds they could use.

It was understood that they did not have knowledge about different types of practical work. That was why it was necessary to explain the different ways of doing practical work, in order to get more information about their potential. Some explanation about meanings was especially needed for investigative and illustrative practicals. The ideas about each type will be presented in the next section.

4.2.4 Experiments

Explanations were made by showing some experiments. For instance, for skill-type practical work, separation techniques were chosen as an example and questions were asked about things like 'What could be taught with this experiment?' or 'What pupils should know after this experiment?' The other example of investigative-type experiments, apart from those in table 3.4, was 'How strong is a magnet?'

4.2.4.1 Skill

16 out of 24 teachers said that this kind of practical work "makes pupils gain abilities and skills like how to use equipment" so that they can be prepared for future experiences. The other ideas are substantive or just general thinking such as "It consolidates knowledge" or "It makes pupils interested."

4.2.4.2 Illustration

The ideas about illustrative practicals are classified below:

1. "It supports the theory and consolidates knowledge because pupils see the theory in action."
2. "If the instructions are given then it is easy to do, so it is preferable."
3. "It is easy to manage the class because everyone does the same thing."
4. "Pupils gain manupilative practical skills."
5. There is one negative idea that "It is a waste of time, there is no value spending time with this because pupils already know what they are going to find."

4.2.4.3 Demonstration

It is clear that this type is used mostly by the teachers when they do practical work. They use demonstrations because classes are crowded, so in terms of management it is easy. There is not enough equipment and time, some experiments are dangerous and some pupils are of low ability. The teachers stated that there really was no alternative because of the reasons above, even though they realised that just watching was not enough for pupils.

4.2.4.4 Investigation

After gaining some information about the structure of investigative work, teachers provided some ideas in relation to their situations and conditions. The first question in their mind was 'if they can do it or not,' instead of 'What is the outcome of this in terms of pupils' learning?' Actually, it was not fair to expect to hear about procedural ideas from them, as they do not have the background. The consensus was that *"It is more scientific and creative as pupils discover and find out something by themselves,"* and *"Pupils use and develop their thinking as they have to make a plan and then carry out an experiment."*

However, there was always a negative side. Except for two teachers, they all agreed that having investigative-type activities was an impossible mission. The reasons for that are given below:

1. It is time consuming, and the teachers already have difficulties finishing the syllabus.
2. There is not enough equipment.
3. Since pupils are doing different things at the same time, it is difficult in terms of classroom management.
4. Teachers believe that pupils can not do everything by themselves; for instance, they can not make plans by themselves. Pupils' abilities have to be high.

As can be seen, there were no procedural ideas coming from the teachers.

4.2.5 Summary of problems and reasons for not doing practical work

The biggest problem is the university entrance examination at the end of year eleven. It is a two-level exam to eliminate students according to their grades. For example, in the year 1997 when the applicant figure was 1,398,595, the number of students who passed was 445,226. It is evident that this is a major competition for pupils. Even THEY do not want to spend lots of time doing experiments. The full syllabus must be completed.

Other problems include lack of equipment, absence of technicians, very crowded classrooms (at least 40 pupils), and lack of laboratory training for both pupils and teachers. The teachers want some guidance and training materials, such as books.

More emphasis on practical work must be given in pre- or in-service training. And they admit that they themselves have to be more creative in terms of time and variaty of experiments. Similar results are also found by Asici (1992), and exactly the same findings by Cepni et al. (1995).

5 Discussion

In the previous chapter, the results have been presented descriptively and we have some ideas about ongoing practical activities, as discussed by the interviewed teachers from a range of schools. Although there was not much information about practical work in Turkey, we can nevertheless say that we learnt much about their practice of teaching science.

The results have given basic ideas about the purposes of practical work, the types of practical work, and some classroom observations in terms of procedural understanding.

That the teachers generally acknowledge the benefits of practical work without thinking of its purpose or learning outcomes is seen in this research, as has been noted by others (Gott and Duggan 1995). Yes, it seems to be a positive activity – but what is it teaching pupils? Why is it a good thing? The generally emphasised answer is that 'it helps understanding'. When the teachers say 'understanding' they seem to mean mainly in a substantive sense, as in learning theory better. As noted earlier the research into children's understanding (Pfundt and Duit, 1991) does not support this assertion.

According to the responses during stage 1 (table 4.2) only 30% of the teachers mentioned procedural ideas, mostly involving manipulative skills rather than specifics about obtaining data and evidence. The skills discussed included such things as using equipment like a thermometer or a bunsen burner or setting up apparatus, and presenting the results in a table. Actually, much research evidence pointing attesting to the development of manipulative skills as the essential function of practical work (Woolnough and Allsop, 1986; Campbell and Wilson, 1998; Wellington, 1998; Gott and Duggan, 1995). I agree that these skills should be known by pupils to obtain reliable data; but they are not the only reasons why we should do practical work. Learning just these skills gives pupils only the ability to handle things manually. Having procedural understanding, which is about scientific process, however, gives them the ability to solve problems in many aspects of their lives by applying the knowledge of scientific process to familiar or unfamiliar situations. Because guidelines are outlined in the NC, it was expected that teachers might say more about such specifics, but only one teacher says what should be taught. If pupils are not encouraged to understand and use procedural understanding, what is the point of doing practical work? Is the point to have them develop manipulative skills? Unfortunately, teachers had little or no say in what they were to teach.

During the second opportunity, having knowledge about the types, especially investigative work, increased the emphasis on different aspects in terms of procedural understanding. The teachers know the types of practical work but they do not realise their different outcomes. On the other hand their understanding is confused about the understanding of the investigations with discovery approach. According to their understanding investigations are for pupils to do or find something on their own (which is about discovery work) rather than developing the understanding the concepts of evidence.

What they say is presented in table 4.3. Of all the types, the teachers prefer recipe types and demonstrations.

There is a belief that "*demonstrations are quite nice for chemistry because you can have something on your desk and everybody can see it. But in physics, in terms of the readings on the meters, demonstration is not ok*" (teacher 4). This means that having some skills is important for pupils. However, physics is not the only subject which requires measuring skills. On the other hand, for visual and dangerous experiences like investigating the reaction of sodium with water, demonstrations are good opportunities. But, it would not be sufficient, for example, to just demonstrate the reaction between marble chips and acid where pupils can use their investigative abilities with the understanding of concepts of evidence.

As an illustrative or recipe-type of experiment, a teacher gave the concept of electrolysis as an example: "*...the theory is that some particles are charged and they* *are called ions. Do the illustrative practicals; there are gonna be some predictions about what is going to happen. And then link the idea of particles in a beaker being charged; they move electrodes to see if their predictions are true...*"

In the above example, there is a theory and the aim of the practical is to back up this theory. But does this really back up the theory that some particles are charged and they are called ions? Is there any evidence for pupils to understand that their predictions are true? Such things the teacher did not point out. There is no point given by the teachers such as if the practical done like above example is going to work or not. The answers for the questions actually depend on the teacher and how s/he carries out the practical, which points s/he emphasises, rather than on pupils being taught to use their procedural understanding or even to have this understanding.

The recipe-type practicals are said to be preferable because of managing the class, since it is said that "*all the pupils end up with the same results.*" Results are not, however, always the same, as is claimed; pupils can end up with different results. In these circumstances, the five main areas of procedural understanding must be taken into consideration when pupils are doing experiments by themselves. On the other hand, if an experiment goes well, pupils may think that everything always works well and that everything happens spontaneously. Without procedural understanding, how would they understand the nature of science?

There is of course an investigative type of practical, but the teachers' responses talked mostly about the difficulties with investigative work. As is stated in the previous chapter, these difficulties arise because of limits on time, equipment, students or the teachers themselves, and the fact that pupils are nevertheless being assessed about investigative work, that being compulsory. Wilkinson and Ward (1997a) found similar problems with the teachers during their work which examined students' and teachers' perceptions about the purpose and effectiveness of lab work, as did Donnely et al. (1996). According to the responses of the teachers in this study, time is the biggest problem in finishing the syllabus. The reason given for this is that investigations take a very long time to do and students would probably not get through the theory. It is in fact correct that investigations may take longer than an ordinary practical such as a recipe or a demonstration.

Osborne (1998) questions the major warrant for devoting much time to such practical tasks and pupils' needs for such skills. Most teachers would probably like to agree with him but I believe that understanding procedural ideas is necessary, and the way to understand them is to conduct investigative work. The pupils need to collect data in order to appreciate the issues relating to the procedural understanding especially those to do with reliability as they need to repeat readings or chose the right instrument and so on. Additionally, as it has been pointed out that it is more useful to have pupils experience the work themselves rather than demonstrating, then it should be better for them to carry out investigative work by themselves. If we do not want to spend time that can be used for the theoretical work, however, alternative ways can be found. For example, students can make plans at home and prepare for the practical beforehand.

Whether pupils need such skills is another discussion point. According to the findings of PACKS (1994), it is agreed that "understanding of scientific procedures should be seen as an essential component of science education in its own right, and not simply as a tool for the development of content knowledge". I believe that making decisions about variables, making a fair test, knowing about reliability and validity issues, will develop abilities useful in pupils' whole lives, especially when they need to solve problems. Even I, having learned more about these procedural ideas during this doctoral process, have changed some of my points of views in terms of generating ideas from situations or evaluating an idea.

The main emphasis was to see if the teachers have knowledge of procedural understanding. According to the table 4.4 (stage2) which presents teachers' ideas of investigative work, the number of teachers who mentioned procedural ideas was 12. Knowledge of the fair test idea is common, with the realisation that there have to be variables or that pupils should make a fair test, without necessarily giving details as outlined in the previous chapter. The number of teachers mentioning decisions and reliability issue is again low. We can say that they have at least some background knowledge of the aspects and it is expected that they teach these ideas to their pupils.

We should bear in mind that with this second chance, they started to explain their problems as well rather than just their knowledge of procedural understanding.

Investigations seem complex to most teachers. The number and the quality of responses seem to demonstrate that they do not really understand the knowledge underlying procedural understanding.

After that they were given the third chance with some specific experiments. It seemed that this three stage questioning design were working although again the emphasis was on substantive knowledge.

Three tables, 4.2, 4.4, and 4.7, show us what the interviews revealed about teachers' knowledge as reflected from the NC. Table 5.1 presents those three as a whole. It is more obvious here that the teachers did not mention procedural ideas much. The real understanding of the ideas is shown in capital letters. For example, 'f' means that the teacher used phrases such as "*pupils should learn a fair test*" like teacher 11. These kind of answer did not include a detailed and sensible explanations which is assumed that teachers do not have adequate knowledge whereas 'F' means the teacher explained fair test properly and s/he understands the idea.

	1	2	3	4	5	6	7	8	9	10	11	12
Purpose	√	√	-	-	√	-	-	-	-	-	√	-
Inv/type	**F, D, R, P**	f	d	p	-	-	-	-	-	f	-	f, d
Inv/exp	**F, D, R**	f	f	-	-	**D, R, P**	**D, R, P**	-	f	d	f	f, d

	13	14	15	16	17	18	19	20	21	22	23
Purpose	-	-	-	√	-	-	√	-	-	√	-
Inv/type	f	f, r	-	p	-	**R**	-	f, d, r	-	f	-
Inv/exp	f, d, r	-	f	-	f	**F, D, R, P**	-	f, d, r	-	-	f, d

Table 5.1: Summary of the responses during interviews.

Only 2 teachers (1 and 2) were talking from the beginning. The first one was in details and the second one was only the idea of fair test.

6 teachers (6, 7, 9, 15, 17, and 23) did say nothing until the third stage. If we bear in mind that for the first category except teacher one the others was talking about just manipulative skills then we can include teacher 11 to this category.

7 teachers (3, 10, 12, 13, 18, 20, and 22) started talking when the idea of investigations was being discussed.

2 teachers (5 and 19) mentioned only gaining skills or using skills in the aspects of purposes.

2 teachers (8 and 21) did not mention anything at all in terms of procedural understanding.

This table shows that only four teachers have real understanding of procedural ideas as outlined in the concept map. From this table, and considering what the teachers said during the interviews, I can describe three types of teachers or understanding: teachers who seem to understand the notion of procedural understanding; teachers who just know traditionally that there are terms such as fair test or drawing graphs; and finally teachers who seem to find that teaching substantive knowledge is enough but not strictly disagree with the idea of teaching investigations or procedural knowledge. However, If the attitude is 'Who cares about NC" – which seems to be the case – then all the efforts being made by curriculum planners and by researchers are wasted. There are also teachers who were actually hostile to the idea like teachers 15, 16 and 21.

Table 5.2: Types of teachers.

Teachers	Type 1	Type 2	Type 3
1	√		
2		√	
3		√	
4			√
5			√
6	√		
7	√		
8			√
9			√
10		√	
11		√	
12		√	
13		√	
14		√	
15		√	
16		√	
17		√	√
18	√		
19			√
20		√	
21		√	
22		√	
23		√	

Table 5.2 illustrates the types of teachers according to their responses. It seems that though they have ideas, most of them do not realise the knowledge underlying procedural understanding, only four (from different schools) out of 23 teachers recognise procedural understanding in practical work. The major emphasis was on substantive understanding. Unfortunately the responses about procedural

understanding is very low. Since they have been given the chance to explain their knowledge three times and the sample is reasonably representative I do not think that the way of collecting data is responsible for these responses. If they did see that procedural understanding as something to teach i.e. a purpose of practical work, then of course it would have come out. According to the different approaches classified in chapter 2 there is a distinction between investigations with the emphasis on quality of data and the other types. It seems that teachers do not understand that the aim of investigations is to develop pupils' understanding of concepts of evidence. Only type 1 teachers do see the difference. Type 2 teachers on the other hand have a process interpretation such as fair test or drawing tables or graphs. Finally, according to the approaches, type 3 teachers see investigations as a discovery approach and also for substantive understanding. It is acceptable that investigative work is a poor way to teach substantive ideas in comparison to traditional (even so, research does not support the assertion that practical work helps with substantive understanding) but these teachers do not see procedural understanding as a set of ideas to be taught. Those who do not like investigations believe in the traditional approach; the others like type 2 teachers, have sympathy with the spirit of discovery but appreciate it does not work for some reasons such as the time limit.

What might be the reason for this? Is that because of the problems they are having? It is believed that the problems with investigative work which teachers stated might play a considerable role on these misunderstandings. Next focuses on these problems.

According to the responses, it was understood that they are having difficulties or believe that for various reasons, it is difficult to carry out investigative work. The table below summarises the problematic aspects that teachers pointed out.

Table 5.3: Most common problems with investigations.

Time limit	Finishing syllabus, preparation and carrying out, and marking.
Equipment	Not enough
Students	Less able; do not learn; concentration span.
Management	Teachers and the size of classrooms.

The table illustrates that 'time limit' has been stated most commonly. For instance, it was said, "*the more time pupils spend on the investigative work, the less time they have to spend on theory, which is worth 75% of their final grade.*" According to this statement, it is also clear that the emphasis is on theory work. The reason why teachers spoke, earlier and later, about more substantive ideas might be the assessment system. Because of the final grade percentages, teachers might not give importance to procedural ideas, affected by the system in which they teach. It is also claimed that "*it is impossible to mark pupils' work if they are doing 10 or 11 investigations.*" It must be impossible if the teachers do not know what they are looking for when they are marking.

Time is a problem with assessment geared towards substantive understanding and they also need to assess procedural understanding which however can also be taught with paper and pencil. About this issue teacher 15 expressed her/himself as to why s/he does not accept the idea of investigative work or the assessment procedure:

> "*...the amount of the data pupils have to collect to get something realistic is just enormous and you can't afford that amount of time...so you have to ask yourself 'Is it fair on the kids to have them doing 10s of hours of work, possibly even over 100 hours of practical work to get this data and work out(for example) what makes that lead acid accumulator?' The amount of time they put in could have been much more usefully used in other areas... The rules are somewhat simpler now for the practical assessment...The practical assessment is important, because to get top marks ...It is an inefficient way of measuring their ability. Whereas in chemistry, if you give a kid 3 white solids and you say what is this, now you know how difficult it is for a kid to go through an analytical procedure. And yet the National Curriculum criteria and as they are interpreted by the exam boards...So the assessment vehicle we have to work in, has forced us to make some decisions about the way that we teach practical chemistry which may not be those which we chose for ourselves*".

This teacher seems to have some misunderstanding of the methodology of practicals, since I believe there is no need for the process to be so complicated and time-consuming and there is also no need to do all the practicals in an investigative way. Investigative work is not aimed at identifying unknown things in an analytical process, as the teacher suggested in the example of 3 white solids. S/he sees this as a 'discovery' approach and also sees the purpose as to teach substantive ideas. Because of this misunderstanding or maybe for some other valid reasons, s/he feels pressure on her/him about investigations being compulsory.

Again with the same misunderstanding (mistaking the purpose as to teach substantive ideas and seeing it as a discovery approach) with another teacher (21) is that s/he does not like investigations because s/he believes that "*...they seemed like a lot of time wasted and whatever was needed to be taught could be done in five minutes instead of pupils having to do it and having to write it up.*" This would be true only for substantive knowledge but not procedural understanding. I believe that we should pay sufficient attention to teachers when they say "*...there is no value in doing it, it is a waste of time, students do not understand.*" It indicates a problem somewhere between the curriculum planners and the teachers.

Here is an another unhappy example: (teacher 16) *"Just doing a piece of practical work, where you give them some instructions is just as valuable as investigations because it teaches you the principle. I think that's probably more valuable in a lot of cases because you do have to know how to investigate and how to set out an investigation...somebody has got an idea that you just can not put into practice in a school lab because you haven't got the equipment or the safety procedure or the time to do it. I don't think it is worthwhile. It is just a new idea... it is a slower way of getting to the same end result in the process.*" S\he does not recognise the separate body of knowledge.

Teacher 13, "*...we've also got the problems that in some areas practical work lends itself more to some subject areas that it does to others, because of the nature of what demands are. It is very quantitative, which makes biology investigations very difficult. If you are doing a biology investigation, which has to be quantitative, they've got to be carried out usually over a very, very long period and you can't do that. So you are limited in what you can do.*"

Equipment is also mentioned as a difficulty, in that there is not enough for everyone to do investigations. However, there is no need for expensive equipment to collect data to consider its quality. Specialised equipment such as Geiessler tube can be used to illustrate substantive knowledge. Besides, this I found very surprising since England has had practical-based science education for more than a hundred years, and economically England is a developed country.

Another difficulty is the students themselves. According to the responses, investigations require them to use their thinking as well as their practical skills. It is said to be difficult for students because they have to put their knowledge into practice. There is a clear contradiction because previous statements show that students have difficulties using their thinking and do not have the knowledge of doing experiments (the teachers meant substantive knowledge; they do not talk of procedural ideas) which the other types of practicals teach. Maybe teachers do not know or are not sure what exactly to teach. They have in fact already said that they need guidance. This again shows that the NC is itself is not enough for teachers. Teachers claimed that it is not easy to do investigative work with some students because they are less able or they can not concentrate for a long time. With less able students it is believed that they can do work on investigations but will not get the same meaningful results as able students. The teachers are again judging this on substantive grounds. Again it is because of the confusion with the discovery approach as they believe that it is not a good way of teaching substantive knowledge. However we can not know what even less able pupils could achieve with procedural understanding since we have not really tried to teach them these ideas.

Teachers agreed that even though students may not have problems, it is still difficult in terms of class management: as pupils are all doing different things, it is, they say, very difficult to keep track of the whole class. But perhaps they are all doing different things because they do not know how to go about the work. Pupils should not be left in the dark. If students do not know what to do, it may be an indication that perhaps there is a problem with teaching methods. Teachers also should not be left in the dark; they need to be taught how to teach such skills and concepts. Teachers also can not manage the classroom for some reasons such as the lack of variety of experiments or the size of the classrooms. Yes, the variety will help to illustrate the ideas and also with the focus on quality of the data but not just substantive knowledge will help some problems to disappear.

Some teachers claimed that the syllabus is not suitable for carrying out investigative work. If they believe so then they should not be happy about it being compulsory. There may then arise other problems such as insufficient satisfaction in teaching and a resulting decrease in productivity. Being investigations compulsory, is both a problem and a reason for teachers doing investigative work in terms of assessment. In this group, two teachers emphasised this statement. One quotation is as follows:

> "*We have science investigations as a core and all the GCSE examination boards in this country have Sc1 investigation course work. That is the reason we do it. It is a good idea in practice. I do not think the syllabus is set up to be able to teach like that. In other words, the way they are examined at the end isn't like that. There is a lot of information you've got to get over, in order for them to pass the exam at the end and do well and being able to teach it all in a very applied way. I do not think it is possible, I think that's why it is falling apart because the drive to work through science investigation as much as*

possible has somewhat diminished."

However, related to the statement above, the teachers also feel obliged to do investigations because pupils should get good exam marks since they are going to be examined. And teachers want their classes to get the best marks possible for the pupils' sake.

In general, investigations seem complex to some teachers and it is a difficult issue although it is stated as compulsory in the National Curriculum. All practicals might indeed be comlex since there are so many ways students can go in terms of substantive understanding but if procedural understanding is seen as the purpose then it is not so complex. The quality of the data should be the central issue. If the attitude is 'Who cares about NC" – which seems to be the case – then all the efforts being made by curriculum planners and by researchers are wasted.

Practical work is being carried out in the schools but gives fewer opportunities for pupils to think of scientific process or to design investigations. So only one of the aims of science teaching would be, doubtfully, achieved – teaching theories.

Considering that investigations have been mandated by the NC since 1989, the teachers have not assimilated the idea well. Although the practice of science derived from AT1, perhaps because of its deficiency teachers did not reflect and provide a foundation for the emphasis given in the NC. This seems to be the fundamental problem with Sc1 applications, as Donnely (1995) also found that the written prescription of what should to happen in classrooms, as laid down by Sc1, is different from what teachers actually practice. Although teachers spend a reasonable amount of time with practical work, they seem unsuccessful in fulfilling the procedural ideas, which are stated in the NC. It seems that there is no clear thinking. Also, as Gott and Johnson (1999) claimed, there is a serious mismatch between the rhetoric and the reality. The investigative approach was designed to reinforce and increase practical work in science but it seems to be having the opposite effect (!) after seeing the ideas of teachers. Actually, we can not only blame the teacher as NC is questionable itself. If it is agreed that there are targets to achieve in the NC, then it seems that there are also problems to solve first in terms of teachers' understanding.

What about the Turkish teachers? Do they reflect the foundations of their curriculum? I think they do. In Turkey there has usually been a search for ways and purposes for integrating new ideas into the existing system. There were attempts to copy or adapt some foreign curricula, whose implementation ended unsuccessfully because of funding problems, it is said. Even without the funding problem, I believe that it is difficult or maybe impossible to implement or 'copy' a system from somewhere else because of factors such as cultural differences and background. For instance, having heard the Turkish teachers' views, I believe it would be disastrous to adopt the English system as it is. This feeling is somewhat frightening to me, for the book written by the NEDP sounded similar to the English curriculum. If an idea or a system is to be assimilated, it has to be made suitable for the people and it has to be implemented in stages. We can not just explain, for example, procedural ideas to Turkish teachers in the same way they might be explained to English ones- however, it has not worked in England anyway. Surely, although we want the same kind of scientific understanding in our pupils, we should design and develop our own curriculum considering our national needs or our existing information. Improving an educational system definitely should not be by wholesale changes to the curriculum or by adopting another country's system. A process beneficial for one country could be inappropriate for another one in terms of the outcomes.

So the aim here is not to say "The English system is good so we have to do the same." My aim in interviewing teachers in two different systems was not to compare the findings either. Considering that the purposes of investigative work are very valuable and that there is a long history of practical work in England, it seemed to me beneficial to know what is happening. The aim was, therefore, to find out what is going on with English teachers, what their problems are and what is said in the NC, especially about practical work, before introducing a new idea. It is important to take the findings into consideration before making a new start.

Unfortunately, for many reasons, the Turkish teachers' responses did tell us that they have no understanding of practical work, and I therefore believe that there is a great need in teacher training programmes. The table, which explains how much time they spend with practical activities, shows that there are some practicals going on. In the month's time of my fieldwork, I had the opportunity to observe only three practicals, but I am not forgetting the fact that two of them were prepared for my observation. One of the practical activities was to find the melting point of naphthalene. It was totally a recipe-type experiment. The second one was to demonstrate that different gases produce different colours when conducting electricity under low pressure, using Geiessler tube. Finally, the third experiment was a teacher demonstration showing pupils how a weight stretches a spring.

The lack of practical work was not because they do not have a variety of experiments, but because of the problems that they are having, they stated. I had a chance to examine some texts and at the end of each unit there is at least one practical activity for pupils to do. Almost all of them are illustrative recipe-types, to consolidate what students have learned in the lesson; but they just remain in the books rather than being put into practice. For example, I myself was not personally involved in any practical activity when I was in secondary school; I remember just one of the teachers doing an electrolysis experiment in front of everyone.

The purposes that the teachers stated for doing practical work are similar to what most research findings say. Although some said, "practical work teaches students how a scientist works and thinks," they did not give an explanation about what that really means. Yes, it is stated in the new TNC (Turkish National Curriculum) that the activities during practical work should be making predictions, hypothesising, planning an experiment, observing, recording results, and analysing data, but there is no explanation.

The teachers have common problems like equipment, training, or time, but the biggest problem is the university entrance examination and therefore time limits. Cepni et al. (1995) suggested that one way of solving the time problem is that the academic calendar should be longer. I do not agree because if the time is longer then we need to solve more problems for the university entrance examination. The system should be changed; or if it is so difficult, then the syllabus might be limited for the exam. It does not have to cover the whole curriculum.

Now the country is in the process of developing a new teacher training programme. Within the science programme, different points have been made in terms of practical work, as is explained in chapter 2. A review of the literature and the new plan shows that mostly ideas have been accepted from Ayas, Cepni and Akdeniz's research. Bearing in mind that they did their PhDs in England and that some of them are the authors of the new plan, it is not surprising that the ideas are more or less the same as those in England. Since I have done my research on this subject in England, I may understand what they are actually trying to say. But what about the teachers who have the actual responsibility of teaching these ideas? I am not saying that the teachers have a lack of ability to understand; but the point is that objectives and methods must be clear and precisely stated. If we simply copy (even it seems that it was not fully explained in England either), it seems that we will make the same mistake again. That is why it is difficult to understand the new plan clearly. That is why there are even mistakes. For instance, in the section on experimental process when an example of rate of reaction is given, the explanation for controlling variables seems wrong, and fair test is not mentioned. With such a model, how can we expect teachers to understand?

As well, according to the teachers' responses they all agreed that investigative-type activities are an impossible mission for the same reasons which English teachers also stated.

6 Conclusion

This study is an attempt to examine how the great expertise reviewed in the literature is manifested in the experiences of real teachers using practical work in science lessons. This would help to clarify teachers' ideas on procedural understanding of science. Therefore, the aim of this chapter is to look at the study critically, especially with reference to the literature review and the findings, in order to make some suggestions regarding implementation.

I examined some ideas of what is happening in both countries in terms of teachers' and researchers' points of view. Surveys and the National Curriculum show that there are some requirements that pupils should understand the knowledge underpinning procedural understanding. This, of course, depends on teachers' understanding and their subsequent teaching of these ideas. Teachers do practical work for the reasons stated in the literature review and also for the reasons given by teachers in this study. Like other studies, this research showed that the first stated reasons were always to support theories and to motivate students. Only lastly did the teachers speak about giving students some procedural understanding, which is not expected as such from the curriculum's attainment target 1.

As was stated before, teachers are supposed to lead students to explore and investigate science and to develop an understanding of scientific investigation. Do teachers really do that in their science classes? According to these research findings, which support some of the findings in chapter 2, teachers' understandings of procedural ideas are not sufficient to enable them to teach them accurately. It has been recognised that teachers need to know and understand about the nature of practical work as it is basically summarised in the National Curriculum and expressed by some researchers. This is also necessary for being successful in implementing the requirements of AT1. Therefore, there should be a significant relationship between teachers and the curriculum developers. More importantly, what is responsible for the inadequate conceptions of scientific procedural understanding held by science teachers? Is it teacher-training programmes or is it the teachers' unwillingness to follow the requirements or is it the over-emphasis on investigative work being compulsory? This is not easy to answer, of course, because what teachers believe is what they know, and what they know is what they believe is right for them. First, let us see if the stated requirements in the National Curriculum about Sc1 really give an idea of procedural understanding. We will then have a clearer picture of whether or not teachers are the only ones to blame.

According to the Sc1, '*pupils should identify the key factors in situations involving a range of objectives, and make predictions, systematic observation and measurements using a wide range of apparatus*'. This sentence, as one example, is not clear to me regarding what one is to do. The first target, also, mentions about repeating measurements, presenting data in appropriate ways, drawing conclusions and deciding if the findings are valid or not (this is explained in detail in chapter 2). It seems, however, that necessary ideas of procedural understanding are not stated clearly. If this is the case then it is not surprising that teachers cannot develop an understanding of investigations. However, there are many supporting materials that can be found it seems that teachers do not use them. In this study, most of the teachers had more than ten years of experience, so they were practising when investigative science became compulsory. Therefore the only reference for them must be the National Curriculum, also considering that this would be the easiest material for teachers to obtain. Although the intent sounds promising, according to the findings the teachers who put this into practice are essentially failing in teaching the requirements of Attainment Target 1. However, it seems that they are doing enough to meet the requirements of exam board. The teachers' emphasis regarding the current nature of lab work is mostly on conceptual learning. Many teachers who actually use practical work did not know much about the philosophy of the curriculum. However, I believe that even if teachers' understandings were perfect, some teachers would still not teach as expected, but at least the rate would be higher. Overcoming this lack of understanding could have the consequence of not misleading pupils when science teaching is conducted by practical activities.

Investigation as a compulsory activity also makes the teachers feel uncomfortable, especially those teachers who do not like the idea and would not want to do it. They therefore do not give importance to procedural ideas, which are in fact much related to the nature of science. It is believed that teachers can and will implement innovations effectively and efficiently only if they themselves recognise the need for change and the value of the changes being suggested to them (Kelly, 1990). This will also create the motivation and involvement of teachers, which Dalin (1995) says, is necessary.

However, we should not ignore that teachers do have problems like marking time and class management. Because of these problems, actual practices showed that most of the teachers prefer recipe-type practicals and demonstrations, although most of such activities could be done in investigative ways using procedural understanding. Even more procedural ideas do not always have to be taught through practical work. On the other hand, the teachers have not forgotten the fact that investigative work is part of the curriculum and compulsory. According to their stated ideas of procedural understanding, it is obvious that teachers have some awareness but that they need to be further enlightened.

This lack of understanding and knowledge pushes teachers to try to integrate their traditional experiences into the requirements of the National Curriculum. The National Curriculum should also state what should be done as well as what pupils should learn. There is no information identified about how to achieve to teach the requirements. Procedural understanding is not recognised in the National Curriculum and then by the teachers. To prevent this, the targets must be updated by using the latest research done by experts. After some training given, including teachers in curriculum planning would be another solution. Of course the importance of in-service teacher training programmes should not be forgotten. To identify further factors involved in teachers' problems with procedural understanding, more research should be done, including studies of teacher training programmes. All the effort spent on developing this understanding, like writing handbooks for teachers or working with pupils to understand their thinking, and all other efforts to find better teaching methods, would thus not be done for nothing.

As was seen in chapter 2, the issue has been discussed in England for a very long time, and the current emphasis is on teaching the nature of science, not just theories of science (-however the more lab-approach in England does not make teachers to use practical work properly. Also we should not forget the fact that, as some other research findings (Watson et. al., 1995) suggest, quantity of practical work is of course less important than the quality of the practical in terms of in helping pupils' understanding). In Turkey, however, science teaching is just becoming an issue, with the YOK-World Bank Project. I cannot have an informed discussion about whether Turkish science teachers have procedural understanding because the discussion could only be about whether or not they have knowledge about practical work. It has been found that there are no practical activities going on. As seen, the science curriculum and the lessons are based on theoretical knowledge. When teachers start to talk about practical work, all they can discuss are the problems they are having. First of all, they should be encouraged to carry out practical work in proper ways and teaching the right knowledge. I believe that the biggest problem is aspects of the system like the university entrance examination, which leads both students and teachers to do more theoretical work in order to prepare for this examination. It is difficult to make changes in this selection system, at least now; but in terms of giving importance to teaching the nature of science, pupils could be asked questions about procedural knowledge in this examination. That is, they could be evaluated on their procedural knowledge so that, of course, the teachers have to learn it as well. Of course, this is not the first thing that should be done. The first priority should be given to the curriculum and the teacher training programmes. The aim of the science education should be clarified first. It should be stated that the aim is not only to give substantive knowledge. Actually, development should be parallel among sectors of the system.

One of the aims of the NEDP was to develop teacher-training programmes. Accordingly, they published guidelines for teacher such as the book, which was detailed in chapter two. The explanations about scientific processes, which we can say are related to procedural ideas, are presented in a very complicated and difficult-to-understand manner. This information should be clarified and given in its correct order, with examples. For instance, 'testing scientific knowledge' (in other words, carrying on an investigation) was defined as defining the problem, recording results, formulating and testing a hypothesis, and finally making decisions about accepting or refuting this hypothesis. This definition, I believe, would make most teachers as confused as I was. The explanations of concepts are missing, and the steps of the process are not in order. You define a problem and immediately after record the results?

After that, they classified the scientific processes, which is also confusing. For instance, measuring is a basic process but is also an experimental process. Another example is that of defining variables and decision making: they can also be put in the same classification. So there is a need to clarify and define these for the teachers first. Let us have a look at an example given. The question is about rate of reactions: What is the effect of concentration and temperature on the rates of reactions? The experiment started with measuring and controlling the variables as below.

> **Measuring:** Measure 25ml KIO_3 and put it into a test tube. Measure 25ml $NaHSO_3$ and put it into a flask and add 1ml starch solution.
>
> **Controlling the variables:** Wait for some time in order to provide thermal equilibrium then add the KIO_3 into the $NaHSO_3$ in the beaker, start chronometer and shake it.

These two 'basic' and 'experimental' processes of science look no different from each other. Measuring is measuring and when they say 'controlling the variables' they are actually measuring again whereas they should mention independent variable. Definitely there is no explanation nor definition of variables, or the meaning of 'controlling' them. The next step was observing the blue colour and recording the times. Then it is suggested that pupils should predict: What is the relationship between concentration and reaction time? After that they present the data as a graph but they say 'recording and using data'. Words are used confusingly. Finally, the experiment concludes with hypothesising as to whether their prediction is true or not; but they did not even change the concentration at all the example above is just about temperature. There is no word on obtaining reliable data. Actually in this experiment, as it is given, there are not many procedural ideas that are used, whereas it can be carried out in an investigative way perfectly: (1) choosing the concentration of KIO_3

as an independent variable, controlling the concentration of $NaHSO_3$ and measuring the time (dependent var.); (2) deciding the range of concentration of KIO_3 and deciding how many times to take measurements for reliability; (3) making conclusions and checking reliability and validity. These three basic points were not given.

It is therefore suggested that a number of examples should be practised with student teachers in order to clarify what is meant. They should be made to realise the value of these activities, and the new ideas should be understandable and recognisable to the teachers. In England, even with many materials (I wonder how many teachers actually read or use them) giving with huge emphasis to the importance of procedural ideas, teachers do not have full understanding of the idea. If the explanations provided in that book produced by NEDP remain as the teaching tools, then we will have many problems to deal with in the future.

Some suggestions have been made by Turkish researchers (given in chapter 2) in this area. They have pointed out that:

1. experiments should be made attractive by using coloured slides and pictures;
2. materials for teachers should be produced for guidance
3. teachers have to be able to know how to be creative in making experiments even in poor conditions, and they should be able to produce alternative ways
4. pupils should be assessed from practical work
5. the number of science lessons should be greater

All suggestions involve the encouragement of carrying out practical work and what it is that should be done. For instance, making experiments attractive would only help to motivate pupils or for doing more practical work, increasing the number of science lessons would not work because they would then have more time to prepare themselves for the university entrance examination. As I stated before, there was no discussion about procedural understanding as the idea of doing practicals is not clear. However, since the new teacher-training programme has started with the NEDP, the next research should be about the nature of practical work and the effectiveness of the project on both teachers and pupils, by carrying out empirical research and including involvement with teachers. It is also believed that more research is necessary if we are to address the questions about the effectiveness of on-going practical work. This is actually necessary for both countries.

In summary, England has a long history of practical work with a lot of 'doing' as it was classified in chapter two: traditional, discovery, process and investigation. The evidence reported in this thesis tells us that even though this long history, the responses of the sample of this thesis showed that there is a little recognition of procedural ideas related to the quality of data (concepts of evidence). Major emphasis was to support substantive understanding. Teachers are aware of the procedural process but they do not have an adequate understanding of the ideas (figure 2.1). they do not see the ideas as something to be taught. Based on my data and the wide literature, if I could make suggestions in order to remedy the situation, they would be:

1. Science curriculum developers or researchers or those who make statements on the National Curriculum, should prepare clear statements regarding the purpose

and the use of practical work; what to teach –ideas relating to the quality of data- needs to be clarified. The teachers should be aware that the aim of science education is not just to teach substantive ideas. For that, the schools should have materials as guidance for teachers and students. For example some planned investigations can be presented to them for their understanding, for a teacher must possess adequate knowledge of what s/he is attempting to teach.

2. We should encourage teachers to follow the latest research. It is for them to be updated, and we should make them active within curriculum studies as well. An association could be formed for this purpose, to arrange meetings and to publish articles. We should not just blame teachers for having insufficient understanding.
3. Teachers should be encouraged to give more consideration to the relevance of lab work and learning outcomes.
4. Schools should equip themselves to support investigative work or proper practical work. Money is not the only thing that was a problem. As mentioned, I believe that without consideration of cultural differences and the different educational history, problems would develop even if the money had been found. Teachers have to realise that carrying out practical work with simple equipment can perfectly serve in teaching the nature of science. We do not need expensive specialised equipment. Therefore, the problem of funding should not be an excuse for not doing practical activities.
5. Teachers should realise that in situations where lab activities are impossible they should use whatever available materials are relevant to the subject in order to use procedural understanding.
6. Teachers have to refine their approach to the way they support practical work.

7. We have seen the negative effects of earlier attempts to adopt a new curriculum in Turkey. There were efforts to adopt a different curriculum and it was unsuccessful for many reasons. This mistake should not be repeated.

Finally, I believe that culture has an effect on practice. Like how people know that they should not drive when they drink alcohol, the teachers also know that they should use practical work when teaching science. In the science culture, the reason why teachers do practical work in England is because it has been an issue for a very long time and they have assimilated the idea. The assimilation of teaching procedural ideas also will take time. We could see the difference if a comparative study would be done between experienced teachers and new teachers on their understanding of procedural ideas. It will be difficult to make teachers first to use practical work and then to teach procedural ideas in Turkey. The first attempt can be made starting with doing pilot studies co-operating with teachers in parallel to in-service teacher training.

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