

Practical Work in Science Education:  
Recent Research Studies

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# The interaction between teaching styles and pupil autonomy in practical science investigations

— a case-study

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*The influence of the teaching styles of two teachers on the structure and organisation of investigational lessons is explored. These are shown to influence way in which pupils (aged 12/13) made decisions in different stages of investigational lessons. Each teacher was followed for nine lessons and the actions and activities of the teacher and two target groups of pupils were recorded on video-tape and audio-tapes. The observations in the classroom were supplemented by collecting documentary evidence, interviewing the participants and using questionnaires. The teaching style of the teachers is seen to affect the autonomy of decision-making of pupils.*

## Introduction

Although practical work and scientific enquiry were well established in the curriculum in England and Wales (e.g. DES/WO, 1995), the introduction of a National Curriculum (DES/WO, 1989) placed an increased emphasis on investigative work. The implementation of investigational work has, however, proved problematic (Donnelly et al. 1993; Donnelly, 1994; Donnelly et al., 1996; Foulds, Gott et al., 1992). The Open-ended Work in Science (OPENS) project (Jones et al. 1992) developed strategies to support learning in investigations practical work and found that it was often difficult for teachers to change their practice. The current study explores one aspect that appeared to affect teaching in investigations: the effect of teachers' existing teaching styles.

Investigations can be seen as problem-solving situations in which students make a series of decisions in order to reach a conclusion. Millar et al., (1994) adapted the APU problem-solving cycle (Schofield et al., 1983) to explore the effects of students' declarative and procedural knowledge on the responses of groups of students to different stages of investigative tasks. They saw the stages of investigations as triggers which stimulate selective recall from students' memories in order to construct responses to the task. The students' responses indicated that students were matching the set task to recalled classroom episodes which Schank and Abelson (1977) called 'scripts'. Scripts were modified by students' procedural (knowing how) and declarative (knowing that) knowledge.

In the current study the approach of Millar et al. (1994) is developed in order to apply it to teaching investigative lessons. The study focuses on the effects of the ways that two teachers structured and organised their lessons, on the decision-making of pupils. In particular it explores the influence of teaching style on how two teachers interpreted an intervention designed to enhance the quality of decision-making in investigations.

Previous studies have identified features in a teaching and learning situation that affect how groups of pupils responded to investigative tasks (Jones et al., 1992; Simon et al., 1992; Watson, 1994). Interactions in groups were affected by the pupils' perception of the task (i.e. which 'scripts' are recalled), pupils' procedural and declarative knowledge and the ability of members of the group to collaborate. Significant aspects of the structure and organisation of the investigation lessons were the structure and timing of parts of the lessons, the organisation of learning activities, the presentation of the investigation, the apparatus supplied, worksheets used by students and the nature of classroom interactions including the arrangement and size of student groups.

## Method

Of three teachers initially observed teaching year 8 (age 12-13) classes, two with differing teaching styles were selected for the study. They were observed in nine 50 minute lessons each, in three kinds of lessons: ordinary science lessons; a set of investigative lessons; and, after intervention by the researchers, investigational lessons about the strength of paper chains. The actions and talk of the teacher and two target group of pupils were record-

ed using two video cameras and seven tape-recorders. The 13 hours of video-tape and 80 hours of audio-tape have been transcribed to produce two paths through each investigation, one for each target group. This data is complemented by field notes, photocopies of all the written work, interviews of the two teachers, interviews of the pupils in the target groups and a pupil questionnaire completed by all members of both classes.

The process of analysis has been an iterative one. Data from the different sources has been analysed and descriptions generated from different sources compared. The description presented is the researchers' interpretation of the transcripts and video-tapes, complemented by the perspectives of the pupils and teachers.

### Teaching styles of the teachers before the intervention

Lena and Peter (not their real names) were young teachers with a few years' teaching experience. Both were perceived to be good teachers by colleagues and the researchers. They were enthusiastic, well organised and related well to children. They both saw investigations as giving more autonomy to pupils and Lena also saw them as opportunities to deepen pupils' conceptual understanding.

In whole class work Lena had a friendly and informal questioning style and created the impression that she wanted to hear the pupils' responses and valued them. Pupils thought that 'she had a soft spot for them.' When giving directions she was direct and to the point. In interview she described her role as a teacher:

... there is information that they need to know ... the only way you can really teach them is by telling them it... but some of the time I know that ... I can...facilitate, give them some ideas on how they can find things out.

Lessons usually began with a whole class discussion and then most of the time was spent in small groups when Lena focused on exploring pupils' thinking and what they knew already. In investigations pupils said:

She'd give you, like... a word, and you would have to...build on it...She'd give you like a little clue, and that would make you think further ahead.

In spite of the friendly atmosphere created, Lena had firm control over the class.

Peter's lessons tended to be dominated by whole class teaching. He gave clear explanations but tended to spend quite a lot of time explaining exactly what to do in practical activities. When questioning he tried to get responses from around the class, but a few boys dominated. Peter saw his role as a motivator, transmitter of knowledge and to some extent a controller.

*Peter:* I think the teacher... is sort of the dispenser of information and knowledge... I think to a large extent the teacher needs to be also, if possible, a motivator... and to some extent a controller...

In the words of two pupils:

*S:* He likes us... to listen and to concentrate...

*SE:* He moulds us!

Peter was prepared to give the pupils some autonomy in group work, but felt that in small groups 'there's no guarantee that they'll be...focusing on the work'. In group work Peter tended to focus on what pupils were doing rather than their thinking. This led to a weak knowledge of pupils' prior experiences. There was a clear distance between Peter and the pupils and they sometimes felt uncertain about asking for help. Although he had good control of the class, it lacked the cohesiveness of Lena's class and occasionally there was some misbehaviour.

Both teachers had used investigations with their classes before the intervention but used the words 'investigation' and 'assessment' interchangeably. Their perceptions of investigations were dominated by the National Curriculum:

*Int.:* What do you see as your aims in science teaching?... Would you... say that you've got any sort of priorities? I mean, do you think, number one that anything stands out in particular?

*Lena:* Um, well, I suppose the priority is always to follow the National Curriculum, knowing that they're going to be tested on it at the end of the course.

They viewed investigations as opportunities to assess pupils' procedural knowledge against the criteria described in the National Curriculum.

### The planned intervention investigation

The intervention took place after the teachers had each been observed for six lessons. The researchers planned an investigation about the factors affecting the strength of paper chains with the two teachers. It would take place over three 50 minute lessons. The main purpose of the intervention was to structure and organise the lesson in such a way that it enhanced decision-making processes in the investigation. It was designed to provide time for specific parts of the investigational process: focusing, planning, obtaining evidence, interpreting and evaluating and further evaluation. The learning focus was, therefore, to be on developing procedural knowledge. Aspects that had been emphasised more strongly in this plan, than in the previous investigation, were focusing and evaluating. Previous investigational work done by the classes had treated investigations as written products for assessment. This has resulted in some pupils using an 'engagement frame' (Millar et al., 1994), seeing investigations as sets of routine procedures. The intervention was planned to shift more pupils towards a 'scientific frame', in which they would be exploring the relation between two variables in a more meaningful way.

The focus of each stage of the investigation was to be supported through interactions with the teacher, a series of worksheets, the materials provided for the practical activities and the pupils' experience of the physical phenomena involved in the practical activities (table 1).

Stage of Lesson	Purpose	Structure	Organisation
Focusing	What is the task about? • Present problem to pupils. • Elicit relevant knowledge through practical work.	<b>Lesson 1</b> • Short whole class introduction (3 min) • Practical activity (15-20 min) • Whole class discussion (5 min)	Focus on observation: how and why the paper chains broke and making quantitative predictions. Group work: • Pupils work in friendship groups of 2 or 3. • Each group provided with 8 strips of papers, of different shapes, sizes and types. • Teacher discussion with groups

Stage of Lesson	Purpose	Structure	Organisation
Planning	What are the key variables and how can they be measured?	<b>Lesson 2</b> • Demonstration of how to measure dependent variable (force to break chain) (5 min). • Planning in groups (10 min)	• Worksheet 1: Blank variables to help to identify and operationalise key variables. • Worksheet 2: Emphasis on quantitative prediction and explaining predictions. • Apparatus supplied: strips of paper, glue etc. • Teacher discussion with groups: quantitative predictions and fair tests.
Doing	Decide how to make the chains: operationalise independent and control variables. Evaluate values, number of measurements and controls. Decide on repeats. Judge errors.	• Whole class introduction (3 min) • Making and testing paper chains (30 min)	• Worksheet 1: Use variables table to record measurements. • Worksheet 2: Quantitative prediction and explaining. • Apparatus supplied: strips of paper, glue etc. • Teacher discussion with groups: problems of operationalisation and evaluation of the quality and number of measurements made.
Interpreting and Evaluating	What patterns can be seen in the data? Are the data reliable and sufficient?	• Small group discussion about patterns (10-15 min) <b>Lesson 3</b> • Prepare results for whole class review (5 min) • Group presentation of results (10 min)	• Worksheet 3 guides discussion about patterns and quality of data. • Focus of presentations and peer review is on patterns, quality of data and how it could be improved.
Further evaluation	How can the quality of the data be improved? • Measuring techniques • Range of measurements Can quantitative predictions be made from the patterns?	Pupils work in groups to check measurements, or make measurements to evaluate quantitative predictions (20 min)	• Worksheet 4 encourages pupils to extend their investigation. • Teacher works with groups to set targets for extending investigations.

Table 1: Outline of planned intervention investigation

## Investigation Lessons Observed

This section starts with an overview of what happened in the investigation lessons and then the first of the series of investigation lessons is described in detail to illustrate the effects of the teachers' interpretation of the intervention investigation on the pupils.

### Overview of paper chains investigation

There were some similarities between the lessons of the teachers. Both concentrated on small group work, reflecting the greater openness of the investigation. In both lessons the pupils were unclear about the learning objectives and focused on surface features such as learning that graph paper is stronger than newspaper, or learning how to make a paper chain:

*Int.*: What do you think you've learned from doing your investigations?...

*R.*: ... that graph paper is stronger, that green one.

*Int.*: Right. Is that it?

*R.*: Um...

*Int.*: You spent three lessons doing that, seems a long time to spend finding out that graph paper's stronger.

*JA.*: Yeah, it, and we also found out which, um, which paper's stronger. Not just the graph paper, all of them.

Many pupils approached the investigation as a routine exercise. They saw the worksheets as guiding them through set procedures and many seemed to view satisfactory completion of the investigation as producing a set of completed worksheets. For example, the target group of girls in Lena's class investigated the effect of using different glues to stick the chains. They wrote up their investigation concluding the order of strength of the glues, yet in interview they revealed that they knew that the glue was having no effect on the strength of the chains and that the chain never broke where it was glued. This approach fits well with the teachers' previous use of investigations as 'assessments' in which they used the pupils' written work to assess them.

There were also significant differences. Lena felt it important to give the pupils some responsibility for their own learning whereas Peter revealed a reluctance to hand over control to pupils:

...there's always a slight fear of doing that, that you may not get to a particular group early on, and they may have gone a long way down the wrong route...

Lena's class felt that she listened to their ideas and encouraged them to think for themselves whereas Peter's class thought that direct teaching was more important. The atmosphere in the two classrooms was different: both the pupils and Lena thought the pupils worked quite hard in this investigation, whereas Peter's class lacked cohesiveness reflected in some minor misbehaviour by some boys.

### Lesson 1 of the investigation

Lesson 1 superficially reflected the planned structure for the investigation for both teachers: a whole class introduction, then pupils working in groups to construct and pull apart paper chains and finally a whole class planning stage.

#### The focusing stage

Lena began this stage by gathering the class around her and giving out the worksheets for the planning stage. She focused on making observations of paper chains being pulled apart and thinking about why they broke. She quickly modified this emphasis:

Now, what I want you to do them is to PREDICT together, which LINK is going to break first...

The pupils then worked in small groups. The response of the two target groups to the introduction was quite different. The group of boys immediately began constructing their chain, clarifying their understanding of how it was to be constructed. They predicted which link would break first and pulled the chain apart into successively smaller bits and gave a variety of reasons for particular links breaking first. The girls' group started with a lot of off-task talk. Eventually they started sorting and describing their strips of paper. One girl asked the teacher where she should write her ideas. The worksheet was not designed for this, but rather as a table for listing and deciding values of key variables, but they agreed that the girls should write their ideas on a blank part of the worksheet. The girls then began their writing accompanied by a lot of off-task talk. Later the teacher returned to the group and

the girls wanted to know whether what they had written was acceptable. The teacher said it was and encouraged the pupils to construct the paper chain, which they then did. This was accompanied by a discussion of whether they were conducting a fair test. They eventually decided that they had to predict where the chain would break, rather than carry out a fair test. This discussion was interrupted by the whole class session on planning and the girls never pulled their paper chain apart.

Peter's introduction focused on identifying key variables. It was not until the end of the introduction that he modified this and told the pupils to focus on how the paper chain would break and why.

After the introduction the pupils worked in groups. The girls group made two predictions of which link would break in the chain. These predictions were based on the position and the thickness of the strip of paper. Although different members of the group disagreed on the predicted effects of both these, no reasons were given to support their assertions. When the girls actually broke their chain, it broke near the middle and the girls' discussion then focused on whether the break was actually at the middle or near it. This discussion was unresolved and drifted into off-task talk. At no time did they discuss why it should have broken where it did. During this time the teacher visited the group briefly on two occasions and on each occasion focused on identifying key variables rather than why or how the chain had broken.

The response of the target group of boys in Peter's lesson was characterised by large amounts of off-task talk and minor misbehaviour. They carried out the practical work required, constructing and breaking the paper chain, but failed to engage in discussion about the problem. The teacher visited the group on several occasions for very short periods of time but they continued their off-task talk as soon as he left and sometimes when he was talking to them. Peter's desire to retain firm control on the transmission of knowledge was apparent throughout the lesson. During group work he made frequent interjections to the whole class trying to focus them on particular aspects of the task, typically beginning with, "Please listen very carefully."

#### *The planning stage*

In both classes the planning stage began with a whole class discussion. Lena gathered the pupils around the front and explained how to use the blank variables table in worksheet 1, for planning the investigation. As soon as the class had returned to their seats the girls' group went up to the teacher and

asked for help in filling in the blank variables table, spending about 5 minutes with her. On returning to their seats they were satisfied that they had completed the necessary paperwork and spent the last 5 minutes talking off-task and never pulled their paper chain apart. Meanwhile the boys made a half hearted attempt to fill in the variables table and then spent the last ten minutes chatting among themselves.

Peter introduced the planning stage to the whole class by giving out the planning worksheet and his question and answer session focused on identifying what 'is most important about how the chain might break.' There was no discussion of why these factors affected the strength of the chains or how they might be measured. The pupils then worked in groups writing down the key variables. Both target groups did this in a desultory fashion, spending more time talking off-task than on-task. Paul then had a final whole class session which focused again on what were the key variables.

## Discussion

The study shows a strong interaction between the planned intervention and the teachers' prior teaching styles and views of the role of investigative work in the science curriculum. The teachers saw their role as helping students to master the skills and processes listed in the National Curriculum. Millar and Driver (1989) maintain that the skills and processes of science only gain their scientific character through the scientific purpose and concepts in which they are embedded. If the main purpose of an investigation is to produce a written product for assessment, then the skills and processes needed to perform the activity run the risk of becoming routine procedures to be learnt, rather than something with intrinsic meaning. This can lead to pupils working in an engagement frame; seeing investigations simply as activity.

The teachers' view of investigations as 'assessments' meant that they found it difficult to change to an approach which emphasised supporting pupil decision-making and retained a strong emphasis on producing a written account of the investigation. The orientation of the teachers to assessment emerged when they introduced the investigation to the whole class: both teachers gave mixed messages as to what this stage was about, as it did not focus on a procedure that they would normally assess. The focus shifted from how and why the chains would break, to predicting or identifying key variables. This mixed focus was reinforced by the ways that the teach-

ers adapted the organisation of the lessons, e.g. the ways in which worksheet 1 was used and in the teachers' interactions with groups.

The different teaching styles of the teachers affected how they interpreted the intervention. Lena could adapt her teaching style, whereas the approach intended in the intervention required a radical change to Peter's style. Lena saw investigations as opportunities to develop pupils' conceptual understanding, already placed some of the responsibility for learning on pupils and was used to situations where she encouraged pupils to use and develop their own ideas. Peter's lesson, superficially, was closer to the planned lesson in structure but the message conveyed through his interactions with the pupils was that all that was necessary to complete this lesson successfully was to identify the key variables in the investigation. His desire to 'mould' the pupils was apparent in his reluctance to give pupils autonomy and his frequent interjections to the whole class.

The effect of the teachers' structuring and organisation of the decision-making processes of the groups varied. The pupils in Peter's class appeared to take a passive role. Most accepted Peter as controlling the class's activities and carried out the practical activity but only responded to thinking about the task in direct response to the teacher's questions. The decision-making processes remained mainly with the teacher. In Lena's lesson the response was more mixed. The girls group failed to pick up the fact that the investigation was different from their previous 'assessment' investigation and concentrated on completing the worksheet. They had matched the task to the wrong 'script'. In her discussions with the girls, the teacher inadvertently reinforced this view. The boys group, however, which had less contact with the teacher, picked up the intended focus from the teacher's introduction and carried out the focusing stage in a similar way to that anticipated. What is common to all these groups is that they had no clear idea of the learning objectives of the investigation to guide how they responded to the investigation. Pupils were often observed working in an engagement frame, carrying out practical tasks without understanding and without any clear criteria to evaluate their purpose.

Previous work has concentrated on how groups of pupils respond to different tasks in non-teaching situations. The current study illuminates how different aspects of the structure and organisation of investigations may be mediated by the teacher. Effective orchestration of pupils' decision-making in investigative lessons is a difficult teaching challenge. Teaching style was one of the factors that mediated whether the teachers were able to use new

pedagogic approaches, but equally important may be the ways in which pupils and teachers view the purposes of investigative work.

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