

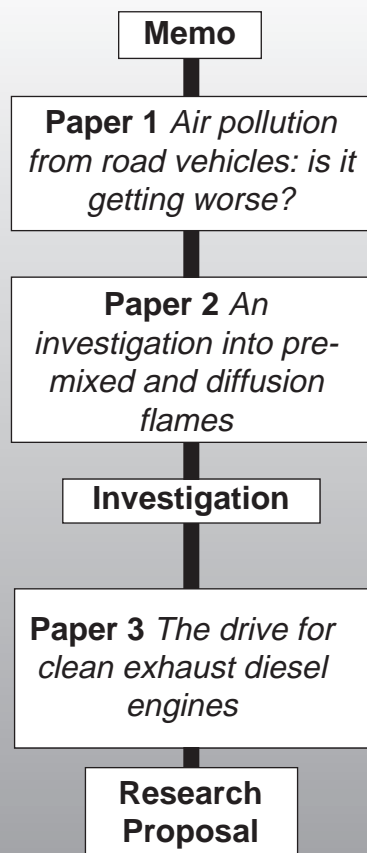
Pupil Research Brief

Teachers' Notes

Syllabus Coverage *Subject Knowledge and Understanding*

- ❑ unless waste is properly treated pollution will be caused
- ❑ most fuels contain carbon, and/or hydrogen, and sometimes sulphur
- ❑ when fuels burn the gases produced may include carbon dioxide and sulphur dioxide, which may harm animals and plants, and water vapour
- ❑ when fuels burn, energy is released as heat
- ❑ gases produced when fuels burn are released into the atmosphere
- ❑ high temperatures produced when fuels burn cause nitrogen and oxygen from the air to form nitrogen oxides

Route through the Brief



Introduction

In this Brief the teachers and pupils take on the roles of research scientists in a chemistry department: the pupils are new research students, whilst the teacher is their supervisor. The department is seeking funding for a new research project on reducing pollution from motor vehicles. The pupils, in their roles as investigators on the project, are asked to help in making the *Case for Support* in the form of a research proposal in three sections. This will go to the Research Council who will decide whether the project deserves support.

Experimental and investigative skills

- planning experimental procedures
- obtaining evidence
- analysing evidence and drawing conclusions
- evaluating evidence

Prior knowledge

Before attempting this Brief pupils should have covered endothermic and exothermic reactions, and energy transfers occurring during reactions.

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Teachers' Notes continued

Running the Brief

Pupil grouping

Pupils could work in a number of groupings during this Brief. Suggestions are:

<i>Initial briefing</i>	-	whole class; teacher introduces the topic
<i>Memo</i>	-	individuals or small groups of 2 or 3
<i>Paper 1</i>	-	groups of 2 or 3
<i>Paper 2</i>	-	groups of 2 or 3
<i>Paper 3</i>	-	groups of 2 or 3
<i>Communication</i>	-	compilation of research proposal in small groups and whole class discussion of work (optional)

Timing

The unit should take 3-5 hours of classroom time to teach. This will depend on the time spent on the investigation. Some of the work could be done as homework.

Activities

Pupils should be issued with the **Study Guide**, which provides them with a summary of what they should produce as they work through the Brief. It can also be used as a checklist so that they can monitor their own progress.

The aim of the work is to produce a **research proposal** for the Research Council which is set out in three sections. These are described in the **memo**.

The memo requires the pupils to work their way through the three papers in order. The papers are from fictitious journals, and have some cross referencing between them reflecting the nature of real research papers. The Research Director has written notes on the papers which suggest things the research team should do. Pupils could keep track of which sections they have completed using the Study Guide.

Paper 1 outlines the issues concerning air pollution caused by burning fuels. A number of pollutants are described. The research team are directed to look at

three of them in more detail using a *jigsaw* technique. This requires each team member to work on one pollutant, and then each member contributes their work to the team to produce an overall summary. They are also directed towards the section on particulates, which is the main interest of the Research Director, who has published work on this before (Paper 2). Health related issues are also emphasised. Work done on Paper 1 allows the team to write Section 1 of the research proposal.

Paper 2 outlines some of the previous work on particulates carried out by the Research Director. In order to provide information in the research proposal about the team's track record in the field, it is suggested that follow-up work is done on at least one aspect related to the Director's research described in the paper. The annotations by the Research Director suggest a number of possible activities (see *Investigation details* in these Teachers' Notes). The activities based on Paper 2 allow the team to write Section 2 of the research proposal.

Paper 3 describes some of the possible ways forward for researchers in this area. The team are directed towards the idea that reducing the production of particulates, by improving the combustion process in engines, is the best way forward. The team need to consider what could be the focus of the proposed research, and to come up with a plan, possibly in the form of a flow chart (see memo). This makes up Section 3 of the research proposal. It is obviously not expected that the investigations suggested by the pupils for this section of the proposal should be carried out. This is an opportunity for the pupils to plan an investigation, with all the usual requirements to make knowledge-based predictions or hypotheses and to consider key variables, but in a context outside the limited environment of a school laboratory.

The research proposal could be presented as a written report, or be the basis of a research seminar, where each team presents its proposals to the whole class. All team members could be involved in deciding which proposal has the most merit, and therefore which one should be submitted to the Research Council for consideration.

Investigation details

Paper 2 requires the pupils to carry out their own investigations. Firstly pupils can find out more about the combustion process by producing a design for an experiment to collect the main products of combustion, CO₂ and H₂O. They can also demonstrate that a diffusion flame (Bunsen with air

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Teachers' Notes continued

hole closed) produces much more soot than a pre-mixed flame (Bunsen with air hole open). This can be done at a simple level by collecting the soot from the flame on, for example, the bottom of an evaporating basin or beaker covered with kitchen foil. Some pupils could develop the investigation further by trying to compare the amount of soot deposited as the air hole opening is varied. This is difficult to do, however. Attempts to detect differing masses of deposits are not always consistent and require very sensitive balances. Pupils may, however, have some worthwhile ideas to suggest.

It is suggested that they could investigate how the heat energy output of the Bunsen flame varies with the amount or rate of oxygen/air pre-mixing with the fuel. This could be done by timing how long it takes to heat a fixed volume of water to a fixed temperature for various settings of the air hole.

They can find out from Paper 2 that the more complete the combustion, the hotter the flame and also the less soot content. Therefore they should be able to relate increasing heat energy output to decreasing soot output. They should also reach the conclusion that pre-mixed flames result in more efficient combustion and less particulate pollution.

There seems to be little or no difference in heat output with the air hole $\frac{3}{4}$ or fully open. Complete combustion of the fuel is therefore probably occurring with the air hole $\frac{3}{4}$ open.

The investigations will provide them with background knowledge about the combustion process and about the causes of particulate formation, using soot as an analogy for engine-derived particulates. This knowledge will be useful later when they suggest a research programme in Section 3 of the Research Proposal. However, the main aim of the activities based on Paper 2 is to allow the team to write Section 2 of the research proposal, i.e. describing the department's previous research (including their own investigations) and track record in the field.

Safety issues

PLEASE NOTE: It is also important that you prepare your own risk assessments for the practical work in this Brief in the usual way.

Using Bunsen burners Pupils should be required to follow normal safety procedures when using a Bunsen and when heating water.

Wear eye protection.

Assessment issues for *Experimental and Investigative Science* (National Curriculum for England and Wales)

P	Planning	O	Obtaining evidence
A	Analysing evidence	E	Evaluating evidence

There are a number of investigations in this Brief.

Paper 2 suggests that pupils design an experiment to show that the main products of burning a hydrocarbon are CO_2 and H_2O . This could allow pupils to achieve mid level marks for all skill areas.

The investigation into the relationship between the amount of pre-mixing of oxygen and the fuel and the amount of soot production could allow pupils to achieve high marks across all skill areas if they use a range of air hole aperture sizes and pupils use their knowledge of the chemistry of combustion to predict and then explain why soot levels decrease with increased mixing of the fuel. The measurement of soot produced is difficult, and this in itself could provide a demanding challenge for pupils. If pupils merely use 'air hole open'; and 'air hole closed' they would be restricted to low marks.

Similar comments could be made about the investigation into the link between pre-mixing and energy output.

Assessment issues for *Experimental and Investigative Science* (Northern Ireland Curriculum)

P	Planning	O	Obtaining evidence
I	Interpreting and Evaluating		

See notes for England and Wales.

Scottish syllabus coverage

Standard Grade Chemistry - *Fuels* and *Carbohydrates*

Further pupil research opportunities

1. Pupils could investigate collecting soot deposits on a glass slide or the base of a beaker from a Bunsen flame with different air hole openings. They could try using a light sensor linked to a PC to measure the amount of light transmitted through the slide or beaker, which could be related to the amount of soot in the flame. Results are inconsistent, but you may feel that pupils could give some thought to this problem - they may have some profitable ideas!
2. It is also possible to measure the relative hotness of the Bunsen flame for different air hole openings by using a thermocouple. If appropriate, pupils could make their own thermocouples.