(i) Taking part in the science investigation

(ii) The experiment with colourless liquids in Phase I

(iii) Making the toy train run by finding the correct combination of switches in Phase II

(iv) (Answer this question only if it applies to you): The written problems about a toy electric train

(v) The lessons on chemical reactions in Phase III (final phase)

(vi) The chemistry experiments (demonstrations) in Phase III (final phase)

3. Please tick the relevant box according to the scale below:

SCALE

1 = hopeless teaching; extremely poor teaching
2 = poor teaching
3 = indifferent teaching
4 = good teaching
5 = excellent teaching.

(1) (Answer: this question only if it applies to you): The lesson dealing with tree diagrams in Phase II

(2) The lessons on chemical reactions in Phase III (final phase)

Percentage of Pupils

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>2</td>
<td>5</td>
<td>38</td>
<td>44</td>
<td>10</td>
</tr>
<tr>
<td>(ii)</td>
<td>1</td>
<td>7</td>
<td>36</td>
<td>44</td>
<td>12</td>
</tr>
<tr>
<td>(iii)</td>
<td>2</td>
<td>8</td>
<td>30</td>
<td>42</td>
<td>18</td>
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<td>(iv)</td>
<td>20</td>
<td>25</td>
<td>34</td>
<td>16</td>
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<td>(v)</td>
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<td>14</td>
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<td>(vi)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Experimental group

Control group
4. Please tick the relevant box according to your opinion:

(i) It is worth working hard for an examination that does not count at all for school marks, such as the science investigation examination.

- [ ] I agree 66% I disagree 34%

(ii) The work on the rate of chemical reaction in the final phase of the science investigation was easy.

- [ ] I agree because e.g. Easy steps were used as well as practical examples; it was explained well and was simple to understand; the transparencies were laid out clearly.

- [ ] I disagree because e.g. We were not allowed to take notes; we had to rely on our memories; I could not remember the work.

THANK YOU FOR YOUR VALUABLE CONTRIBUTION TO THE SCIENCE INVESTIGATION.
4. Please tick the relevant box according to your opinion:

   (i) It is worth working hard for an examination that does not count at all for school marks, such as the science investigation examination.

   % 66 I agree  34 I disagree

   (ii) The work on the rate of chemical reaction in the final phase of the science investigation was easy.

   I agree because e.g. Easy steps were used as well as practical examples; it was explained well and was simple to understand; the transparencies were laid out clearly.

   I disagree because e.g. We were not allowed to take notes; we had to rely on our memories; I could not remember the work.

THANK YOU FOR YOUR VALUABLE CONTRIBUTION TO THE SCIENCE INVESTIGATION.
H.2 Responses from Teachers

The two physical science teachers of the pupils who had participated in the investigation, rated the 161 subjects according to the following scale:

**ATTITUDE TO SCIENCE**

1 = very negative attitude
2 = negative attitude
3 = indifferent attitude
4 = positive attitude
5 = very positive attitude

Their assessment of the pupils was received after the study was completed in order to avoid researcher-prejudice. This is given in condensed form below.

Attitude of Pupils to Physical Science

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3%</td>
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<tr>
<td>2</td>
<td>12%</td>
</tr>
<tr>
<td>3</td>
<td>53%</td>
</tr>
<tr>
<td>4</td>
<td>27%</td>
</tr>
<tr>
<td>5</td>
<td>6%</td>
</tr>
</tbody>
</table>
Dear Pupils,

Here is the report I promised you. Please take it home to show to your parents.

Before I begin, I would like to thank you all for your wonderful co-operation and enthusiasm, without which this investigation would have been an instant failure. I shall always remember you with gratitude and appreciation.

The Aim of the Investigation

The idea was to help you to solve problems and calculations in science more easily. To succeed in this, you need to be able to think logically. The famous psychologist, Jean Piaget, and his supporters claim that logical reasoning cannot easily be taught to pupils, but can usually only develop naturally with time, if at all. The problem is that success in science at school requires logical thinking at an early age, so it would be very useful if the difficulties described by Jean Piaget could be overcome somehow. The investigation that you have just participated in, centres on one of the most important aspects of logical thought, as far as science is concerned. The plan is to show

(i) that pupils can be taught to think logically;
(ii) that pupils who have been taught how to solve a problem, will use their knowledge to solve a similar sort of problem without assistance from their teacher;
(iii) that pupils can be trained to remember the logical approach they have been shown. (It is no use being taught something, if you have forgotten it by the next day!)
The degree to which the investigation has achieved its aim can only be said for sure once all the results have been worked out. Everything looks promising so far, but I shall contact you again to give you the final results.

II. Selection of Pupils
You were chosen from the pupils in Standards Eight and Nine who study science. The method of selection was a statistical procedure, customary in this type of research. The data used to select you were your IQ, age and sex. I substituted numbers for the names of the pupils during the selection, to make sure that I was completely impartial. It was only at the end of the statistical selection that I checked the numbers against your names, so it was very exciting for me to find out who was going to be in the investigation!

Among you was a group of highly gifted pupils, who, as the investigation later showed, do tackle problems somewhat differently from the rest of us normal people!

You were then divided, again by a statistical procedure, into two groups. The one group, as you know, was shown how to work out combinations, while the other group had to work out problems on their own. Both groups were essential to the investigation. Without the co-operation of both groups, the investigation would not have been scientific and the results would have been worthless.

III. Phase I
The combination of colourless chemical liquids is a well-known standard test of logical thinking. The way you set about this problem showed me to what degree you were able to reason logically. For instance, if a pupil mixed the liquids at random, this showed concrete thought only. If a pupil combined the liquids, following a definite pattern, this helped to show abstract thinking. It was not quite as simple as this, actually, because there are several subdivisions of concrete and abstract reasoning.

Many of you have asked me what the chemicals were. Although I changed the labels on the bottles nearly every day, actually you all worked with the same chemicals, in spite of my telling you to the contrary! The chemicals were
(i) sulphuric acid;
(ii) water;
(iii) hydrogen peroxide;
(iv) sodium thiosulphate;
(v) potassium iodide.

Sulphuric acid, hydrogen peroxide and potassium iodide, when mixed together, give off iodine, which is a yellow colour. The addition of water obviously does not affect the reaction, while sodium thiosulphate takes the colour away again. It was possible to produce the yellow colour in only two ways.

IV. Phase II

The first part of Phase II involved the toy electric train which you had to get going by finding the correct combination of switches.

I have a confession to make to you: the switches on the control box were all dummies! The tablecloth on my desk hid a foot-pedal which I pressed whenever I wanted to make the train run. The tablecloth on your desk was simply there to take your attention away from why I had a tablecloth on my desk!

I chose not to press the foot-pedal to make the train go for everyone, in case my secret was more easily discovered. Sorry to have cheated S.G., S.S., C.V. and others, who thought they had failed to make the train go! I really thought my game was up on several occasions, such as when J.A. and R.E. changed the settings of the switches so quickly that I could not take my foot off the pedal in time and the train still careened around the track, although the switches had been changed!

You will remember that half of you had been taught how to solve the train problem. Those of you who had not been shown this, gave equally valuable results in this part of the investigation.

The second part of Phase II was a repeat of the combination of colourless chemical liquids in Phase I. It turned out that nearly all of you had benefited from the investigation.
This time there were two sets of chemicals, apart from the usual changing around of the labels. For both sets, four of the chemicals were

(i) sulphuric acid;
(ii) starch solution;
(iii) a mixture of sulphuric acid and hydrogen peroxide;
(iv) potassium iodide.

The fifth chemical was either water or sodium thiosulphate. The yellow colour was caused by the formation of iodine, in the same chemical reaction as in Phase I. The blue colour was due to the interaction of iodine and the starch solution. The number of colours you found obviously depended on which set of chemicals you had been given. If you had water as your fifth chemical, you should have found four ways of making yellow and four ways of making blue. If sodium thiosulphate was your fifth chemical, there were only two ways of making yellow and two ways of making blue.

V. Phase III

The lessons, followed by the final examination, were crucial to the investigation. The aim was to show that once a certain aspect of logical thinking has been mastered by the pupils, they can apply it to their school science syllabus without further assistance from their teacher. The subject chosen - rate of chemical reaction - was taken from the Standard Ten syllabus, but broadened to show clearly how it applied to everyday life. Unfortunately, owing to the goals and time limits of the investigation, the subject could not be dealt with in depth, to which G.L. quite rightly objected. I am glad, at least, that you nearly all enjoyed the demonstrations of nylon, foam, clock reactions, etc. I had fun preparing them for you.

Many of you were disappointed in the fact that you were given no notes and felt that this was a failing on my part as a teacher. Just be grateful that your other teachers do not inflict the same strain on you! Seriously though, I do assure you that no notes were provided on purpose as part of the research design.

The research design also meant that D.C. and others felt a bit like parrots in the repetitive revision lessons! I sympathise, because I think I would have reacted the same way myself. However, nearly all of you said that the
revision lessons were directly responsible for your success in the final examination. Although I have not finished marking all your scripts yet, most of you seem to have learned a tremendous amount, which is a real achievement without any notes to study from.

The examination required you to repeat the train problem as your ability to remember is very important in an investigation of this kind.

VI. Goodbye
Thank you all again for your contributions to the science investigation.

Till you hear from me again,

Greetings,

from

H A Chandler
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