A methodology for developing science teaching materials for pupils with learning difficulties

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Introduction

Given the diversity of individual needs represented in the field of special education, and the limited availability of suitable published science teaching materials, teachers have met the needs of their pupils by supplementing these in the following ways:

• Using or adapting published primary resources. Care is needed over the age appropriateness of the contexts and any illustrations that are used and the possibility of repetition if the activity has already been used during earlier key stages.
• Using or adapting published secondary resources. This route provides age-appropriate contexts but the concepts, literacy and numeracy demands may create barriers to learning.
• Developing their own resources. Some teachers confident in the use of appropriate teaching strategies for their pupils may be diffident about developing science materials as a result of their limited experience or knowledge of the subject.

This article examines two case studies illustrating the development of science teaching and learning materials at

The question of whether, and how, to adapt existing teaching materials or create new ones to meet the needs of their pupils has always exercised the minds of teachers. Jill Bancroft, from the Science Curriculum Centre in York, uses two case studies to illustrate the sensitivity and understanding required to undertake these tasks. The methodological framework outlined here is likely to provide a useful checklist for busy teachers.

Identifying pupil capabilities

To enable appropriate access, teaching materials must be carefully designed to meet, as far as possible, the needs of the intended audience.

Tilstone (1992) suggested that severe learning difficulties often result from neurological dysfunction or brain damage:

The consequent altered processes may affect the rate of learning, but do not result in a general incapacity to learn. Such altered processes result in a delay, in some or all of the main areas of general development, and sensory and physical impairment which are caused either by the direct result of neurological damage or through the way in which those in contact with the child restrict his or her experiences.

In the development of these materials a range of pupil strengths, in terms of the QCA P-scales in Supporting the target setting process, Guidance for effective target setting for pupils with special educational needs (DfEE/QCA, 2001b), and up to Level 1 in The National Curriculum for
England (DFEE/QCA, 1999), informed the choice of activities, design of equipment and format of pupil resource sheets. Identifying broad areas which create barriers to learning for these pupils helped to identify pupil strengths and increase access to the subject matter. These areas were:

1. Communication methods
2. Literacy skills
3. Numeracy skills
4. Reasoning ability
5. Memory.

Opportunities to develop skills in promoting self-awareness, working with others, decision-making, choosing and taking on responsibility were incorporated wherever possible into the planning of the activities.

Underpinning all aspects of the development of the materials was the issue of age appropriateness. Bancroft (2002) considers the effect of the presentation of teaching materials on the pupils’ perception of their own worth:

Low self-esteem permeates most areas of special need and tends to reinforce under achievement when these students rarely achieve success. In addition, the changes that accompany approaching adolescence heighten the individuals’ awareness of themselves and how they perceive others see them. It is essential that the teaching materials they are expected to work with complement those of their mainstream contemporaries in terms of their maturity, interest and presentation. Only then will the students feel good about themselves and be emotionally prepared for learning.

Context setting

Constructing a realistic context through an interesting storyline, involving the individual on a personal level, acts like a springboard, engaging and taking the pupil forward with enthusiasm and motivation.

When the storyline is explored through role play, and events are experienced in a physical way, children develop their knowledge and intelligence. McSharry and Jones (2000) explain why role play can help to make science relevant to many children:

The desire to play, and therefore to learn, is a fundamental part of human psychology and is a potentially powerful resource residing in the children themselves.

Role play gives children a feeling of ownership of their education. McSharry and Jones (2000) describe ownership ‘as the way a child facilitates their own learning by creating their own role-plays through either scripted or improvised work...’ (p. 74).

Teaching approaches

A variety of multi-sensory teaching approaches using three-dimensional objects, colour photographs and illustrations, sound, smells and tactile materials, all appropriate in the context of science learning, will maximise the use of the available channels for sensory stimuli. This all-round experience gives the pupil an opportunity to use their preferred representational system. In addition, any limitations of any particular sense in receiving information will be minimised if a multi-sensory approach is utilised.

Science investigations provide opportunities for practical work with apparatus and materials. Watson (2001) describes teaching approaches involving direct physical involvement that are particularly helpful to pupils who experience difficulties:

Even expertly presented, interesting information may have little meaning for pupils who lack the basic general knowledge to which it could have been linked. Teachers have somehow to create the conditions for building up appropriate conceptual foundations for subsequent learning. Direct physical interaction with materials is often effective in enhancing pupils’ thinking, especially as many do not spontaneously use verbalisation. Handling physical materials extends their sensory experience, is relaxing and satisfying, and may facilitate mental reasoning.

(p. 141)

CASE STUDY 1: adapting existing mainstream materials

The first case study describes how a mainstream activity, developed for mainstream KS3 pupils and entitled Hot chocolate (Hilton, 1993), was adapted for pupils with severe learning difficulties.

The investigation Hot chocolate was developed at the Chemical Industry Education Centre, part of The University of York Science Education Group. Hot chocolate investigates the effect of different coloured surfaces on heat absorption by radiation. The industrially linked context addresses the real-life problem faced by a chocolate manufacturer when the chocolate in their lorries melted on hot days. The mainstream resource describes, in text linked to pictures, what happened on hot days to chocolate being transported in the company lorries painted purple, and in white lorries which were subsequently hired. Finally there is a suggestion that painting the purple lorries gold (yellow) or in keeping with the company colours could make a difference.

The pupils then plan an investigation to see the effect different paint colours have on the temperature inside small cans. One suggested arrangement of apparatus and the expected results using four paint colours, as they appear in the teacher notes, are shown in Figure 1.
Identification of potential barriers to learning

The ‘everyday’ context for this activity is appealing to the pupil with severe learning difficulties as it is novel, motivating (using chocolate!) and an age-appropriate way of introducing or revisiting the concept of heat absorption by radiation. There are however potential barriers to learning in this mainstream version of the activity which need to be overcome if pupils are going to access the science ideas.

- The title of the activity, Hot chocolate, although a clever play on words appealing to those with a secure knowledge of the vocabulary, may lead the pupil to think the activity has something to do with making hot drinks.
- Some pupils may struggle to make the connection between the colour of packaging of goods being transported and the company colour of the lorry.
- The lamp, as a heat source, is positioned at the side of the vertical can. This arrangement of apparatus does not model the real life context and will prevent the pupil making the crucial connection that the lamp bulb represents the sun above the lorry and the can represents a lorry below.
- Two colours are tested at the same time. The slower worker will struggle to record temperature readings simultaneously and allocate them independently to a table of results.
- Some pupils will not make the connection between changes in air (gas) temperature and the melting of the chocolate (solid).
- The lamp bulb is positioned 5 cm from the can. Pupils may not understand standard units of distance and how to use a ruler.
- For those pupils who do not understand the numerical scale but are beginning to understand that the thermometer liquid rises with increased temperature, inverting the thermometer will cause confusion as the temperature rise is accompanied by an apparent fall in the thermometer liquid.
- In addition, the thermometer will have limited use by the pupil who does not:
  i. coordinate hand and eye to manoeuvre the glass casing so that the coloured line of thermometer liquid can be seen
  ii. understand place value
  iii. sequence numbers to 100
  iv. read small intervals on a scale.
- The temperature is measured at five-minute intervals using a stop clock. Pupils may not understand standard units of time and the small scale measuring five minutes on an analogue stopclock. Furthermore, the alternative of a digital stopwatch will have no meaning to the pupil who does not understand place value and decimal places.
- The results are recorded in a table and plotted to create a linear graph. Pupils may not be able to draw a table or record their results in the appropriate cells and will not be able to create or understand linear graphical representation of the data.

Adapting the material

The initial assessment of barriers to learning and an understanding of the pupils’ many strengths and capabilities inform the changes that can be made to facilitate access to the science ideas.

Renaming the activity Travelling in the minibus focuses attention on a new and more familiar context for the activity. The story line follows events when two pupils travel in different coloured minibuses at the onset of a camping holiday. The chocolate covering on their biscuits melts in the purple minibus but not in the white minibus.

Setting a multi-sensory context not only maximises the capabilities of the pupil but gives them time to consider the problem, a prerequisite to making the investigation meaningful.

Teachers choose the method which best uses the student’s available senses to construct the context for the investigation. Some examples follow:

- The script and role play opportunity (Figure 2) bring to life a midday break in the journey and the students’ surprise that the chocolate has melted on biscuits in the purple minibus but not in the white minibus. Pupils share the reading or act out the parts of the students, introducing a personal element to setting the scene and the problem to be investigated.
- The three-dimensional models (Figure 3) of school minibuses and chocolate biscuits. Appropriate questioning forms the link between the colour of the minibus and the temperature inside. The models can be felt, seen from all sides, and remain throughout the lesson as objects of reference, bringing pupils back on task as their concentration wanes. They provide a focus for generating questions to elicit ideas about colour and heat absorption and to initiate the investigative process.
- Illustrations supporting text present the story and the problem with the purple minibus. The pupil colours each of the minibus outlines to reinforce their understanding.
Travelling in the minibus

The whole class is going camping so two minibuses are needed. There’s only one seat left in the new minibus.

Sarah I want to go in the new minibus.
Tom Why? It’s the same as the old one.
Sarah No it isn’t. The old minibus is white. The new one is purple.
Tom That is the only difference. I don’t mind going in the old, white minibus. Take your share of the biscuits to eat on the journey.
Sarah Ooh, chocolate biscuits. My favourites! I’ll see you when we stop for a break.

It is a hot day. The buses stop for a break after 2 hours.

Tom Let’s eat our biscuits.
Sarah Oh no! Mine have melted.
Tom Mine are alright. I wonder why yours have melted?

Figure 2: Setting the context using scripted role play

How did you make your test fair?

Tick the fair tests

Strategies to support numeracy

The P-scales and level descriptions in the National Curriculum Mathematics document highlight the development of knowledge, skills and understanding in using and applying mathematics, number and algebra, shape, space and measures and handling data. These descriptions informed planning of the materials.

• A spacer, measuring 5 cm, is used by the student to ensure the bulb, used as a heat source, is the correct distance from the can.
• The time taken for a piece of chocolate to melt as it becomes warmer, instead of a thermometer, provides an indication of the temperature inside the can.
• One piece of chocolate inserted into the can opening is prodded with a lolly stick at regular intervals until it melts. Moulded chocolate bars break easily into single, identical ‘fair testing sized pieces’, removing the need to measure the mass or volume of the chocolate.
• Two-minute time intervals are measured using a sand timer in standard or non-standard units depending on pupil capabilities.
• One method of presenting the results as they are collected and omitting the need for a table is for the pupil to collect a coloured cube, the same colour as the can, every two minutes until the chocolate melts. These cubes are assembled to form the first column of a three dimensional block graph.

Apparatus modelling the context

Positioning a single painted can horizontally to represent the minibus, with the lamp representing the sun vertically above it models the real life context. Direct questioning is important to help the student make the connection between the real context and the apparatus used to model it.

Understanding of fair testing when setting up the apparatus is aided by providing a choice of illustrations depicting possible variations in the choice and arrangement of components (Figure 4).
• Pupils can colour in boxes to record results, creating the columns of a block graph (Figure 5).
• Once the procedure has been modelled and carried out by the pupil, it can be repeated using another can of a different colour to make a comparison.

![Figure 5: Colouring boxes creates the columns of a block graph](image)

**Strategies to support literacy**

P-scales and level descriptions in the National Curriculum English document highlight the development of knowledge, skills and understanding in speaking, listening, reading and writing. These descriptions informed planning of the materials.

In the presentation of written text the amount the student is expected to read, and its appropriateness for their reading age, is considered. The use of a large and simple letter style complementing a page format that is straightforward with no indents or distracting areas is used. New vocabulary is used consistently and a small number of key words, on cards, are introduced as they arise.

The actual apparatus or realistic drawings are used in place of conventional scientific diagrams to illustrate the apparatus (Figure 4). Those who struggle with making the connection between symbols and sound (letters in text) will also struggle to identify the symbols used in science diagrams.

Pictorial support using illustrations is used to help establish the meaning of unfamiliar words. Colouring of outlines of a minibus records, without text, what has been found out (Figure 5).

This investigation produces an obvious pattern in the results to help the student conclude that the purple can absorbs more heat than the white or yellow cans. From this knowledge, students can be encouraged to make generalisations about how other colours used for minibuses would absorb heat.

The use of appropriate questioning helps the student to sequence their thoughts logically. Communication and reasoning are supported with the use of sentence openers followed by wide lines indicating clearly the expectation of an achievable quantity of writing or symbols. The versatility provided by an electronic version of the resource allows the teacher to alter text to suit individual needs.

**CASE STUDY 2: developing original materials**

The second case study follows the development of original materials about the science of evaporation for pupils with severe learning difficulties. The principles mirror those used in adapting mainstream resources.

Planning, teaching and assessing the curriculum for pupils with learning difficulties (DFEE/QCA, 2001a) at Key Stage 3 recommends that students exploring and investigating evaporation may:

- observe changes in puddles in the playground, for example, by chalking round the edge, or changes in water left in an open dish, with the level marked, or consider clothes and hair being washed and dried and observe what happens to the water.

(p. 24)

**Creating a suitable context**

To make the science concepts meaningful, a familiar, age-appropriate context that pupils could relate to was identified. The context needed to be the platform for presenting a problem concerning evaporation that could be turned into a question to be investigated with a definite outcome.

The most usual and familiar context for evaporation, that most pupils are likely to have experienced, is the cooling effect of water evaporating from their skin, either as a result of washing or after immersion in water following swimming. As swimming is usually associated with recreation, possibly holidays and enjoyment, this was the context that was selected as it would engage and motivate the student. The investigation *Swimming and Paddling* was consequently developed with the aim of enabling students to observe the changes, including temperature of the surroundings, that occur when water evaporates.
Setting a multi-sensory context involves the teacher choosing the method which best suits their pupils’ strengths.

- A large, colourful **poster and picture cards of people** supported by word cards and photographs provides the seaside location for the story about two young people on holiday.
- The **script and role play** opportunity accompanied by the **sound effect** of seawash, bring to life a girl feeling cold after swimming when she does not change out of her wet swimsuit. Pupils share the reading or act out the parts of the boy and girl, introducing a personal element to setting the scene and the problem to be investigated.
- The **three dimensional model** (Figure 6) made from a plastic bottle with the top of the neck removed and a doll’s head positioned at the top of the bottle models the girl’s body. A colourful lycra band (the ‘swimsuit’) is placed around the bottle. The model can be felt, seen from all sides, and remains throughout the lesson as an object of reference, bringing pupils back on task as their concentration wanes. It provides a focus for generating questions to elicit ideas about what happens when the swimsuit is wet and initiates the investigative process. Allowing students to assemble the model gives them a sense of ownership of the activity, which in turn increases motivation.

![Figure 6: The apparatus models a warm body wearing a swimsuit](image)

**Apparatus modelling the context**

Positioning two bottles vertically, each with a doll’s head at the top, represents identical models of the girl. A wet lycra band around one bottle and a dry lycra band around the other represent the wet and dry swimsuits. The warm water at 40° C in each of the two bottles makes the models feel the same temperature as the human body. Direct questioning is important to help the pupil make the connection between the real context and the apparatus used to model it.

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**Strategies to support literacy and numeracy**

A pictorial equipment list, which is supported by text, enables the student to collect their apparatus independently (Figure 7).

![Figure 7: The pictorial equipment list is supported by text](image)

A ‘me’ thermometer, which uses words to describe a broad temperature range with a scale of five intervals relating to temperatures equivalent to, greater than and less than body temperature, is supplemented by individual pictures on a pictorial scale. Each picture matches a text description on the thermometer (Figure 8) to assist those students who do not read text to work independently.

![Figure 8: Pictures enable non-readers to use the temperature scale independently](image)
Swimming and paddling

Which swimsuit cooled the body most? __________________________________________________

<table>
<thead>
<tr>
<th>dry swimsuit</th>
<th>wet swimsuit</th>
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<tr>
<td><img src="image1.png" alt="Dry Swimsuit" /></td>
<td><img src="image2.png" alt="Wet Swimsuit" /></td>
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<table>
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<th>start = 0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
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<tbody>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Figure 9: Temperature is recorded pictorially to create a pictograph*

**Table 1: A methodology for developing appropriate resources.**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Checklist</th>
</tr>
</thead>
</table>
| 1. Assess pupil capabilities | - P-scale or National Curriculum level in English and Maths  
- Preferred/available representational system  
- Communication methods  
- Memory  
- Reasoning ability  
- Mobility  
- Other |
| 2. Search for activities | - Explore age-related key stage to identify opportunities for progression  
- Match conceptual and practical demands to student ability  
- Ensure clear-cut results that offer a solution to the science problem  
- Ensure it is possible to reach a satisfactory endpoint in the time available |
| 3. Identify a suitable context | - Age appropriate  
- Motivating and engaging  
- Related to familiar experience or interest |
| 4. Identify multi-sensory opportunities | - Visual (pictures and models)  
- Auditory (discussion, sound effects, scripted role play)  
- Kinaesthetic (practical hands-on experience) |
| 5. Design practical apparatus to model real-life context | - Support in making the link |
| 6. Structure discussion and direct questioning | - Appropriate methods of communication to support reasoning |
| 7. Identify strategies to support literacy needs | - Pictorial support for text  
- Word cards  
- Simple font  
- Phrases or short sentences |
| 8. Identify strategies to support numeracy needs | - Number and algebra, e.g. replace the numerical temperature scale with pictures  
- Appropriate measures, e.g. use non-standard units of time  
- Handling data, e.g. omit table and display results immediately in a pictograph or block graph |
| 9. Pilot the activity and revise as appropriate | |
The temperature is measured at five-minute time intervals using a sand timer in standard or non-standard units depending on student capabilities. At the same time the student feels the dry and wet lycra bands to experience the gradual drying of the wet ‘swimsuit’.

The results are presented as they are collected, omitting the need for a table. The pupil collects a copy of the picture representing the temperature on the pictorial scale and sticks it on a time line to make a pictograph (Figure 9).

The results show an obvious difference between the temperatures of the water ‘bodies’ surrounded by the wet and dry ‘swimsuits’ to help the student conclude that the wet swimsuit cools the body more than the dry swimsuit. From this knowledge students can be encouraged to generalise, and consider what they should do when they get wet to prevent them getting cold.

**Conclusion**

To enable appropriate access, teaching materials must be carefully designed to meet, as far as possible, the needs of the intended audience. In this article, I have summarised two different approaches taken to develop science teaching and learning materials for pupils with learning difficulties. The methodology summarised in Table 1 can be used as a guide through the various stages, from the identification of pupil strengths to the selection of age-appropriate activities utilising multi-sensory teaching approaches and strategies to assist independent working. As a means of establishing access to science for pupils with learning difficulties this methodology is by no means exclusive, and represents a methodology for the development of materials in other curriculum subjects.

At the Science Curriculum Centre, the Special Needs Programme exists to develop and provide training in the use of exemplary curriculum materials not only for pupils with diverse learning needs but also as pointers to good practice for all abilities. The programme also supports other curriculum projects to ensure the resulting materials demonstrate an inclusive approach.

In providing a methodology as a framework for writing their own science materials, the hope is that teachers will:

- become more confident in their teaching of science investigations to pupils with diverse learning needs
- employ an improved knowledge of appropriate strategies to access their pupils to the appealing, practical ‘hands-on’ and sensory opportunities that the subject offers
- ensure that activities are matched to the pupils’ literacy and numeracy capabilities
- appreciate, as will their pupils, the benefits of and enjoyment derived from their efforts to create relevant and fun contexts for teaching and learning.

**References**


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