Investigating gradients

A case study of fieldwork and map work with 10-11-year-old children…..

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…..illustrating links with the numeracy concepts of ratio and percentage
INVESTIGATING GRADIENTS

Key Questions
As part of a geography locality study, a class of 10-11 year-olds at Bere Alston Primary School on the Bere Peninsula in Devon went on a fieldtrip from their school to the hamlet of Gnatham on the River Tavy. In preparation for this journey, the children examined an OS map of their school locality. Some of the features discussed were:

- the number of farms on either side of the road that they would travel along;
- the area of woodland along a tributary of the River Tavy and why this was not used for dairy or arable farming.
- the meaning of the black chevron arrows across the road as it approached the river;
- the brown contour lines and whether these could help predict the 'ups and downs' of the journey.

This led me to plan a series of ensuing activities to help the children explore the following key questions:

- How can we measure and describe gradients on maps and in the field?
- How does a map indicate gradients?
- What is the relationship between gradient and land use?
- How can we orientate and use a map to navigate a route and predict the terrain ahead?

Key Concepts
These activities would explore the concepts of:

- gradient, ratio, percentage, slope, change, stability, shape, vertical and horizontal distances, contour, symbol, orientation, direction, landuse.

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one arrow indicates a gradient of **1 in 7 to 1 in 5**

two arrows indicate a gradient of **1 in 5 or steeper**

*Fig 1: A sketch map showing black arrow symbols across a minor road from the children’s village of Bere Alston to the hamlet of Gnatham on the River Tavy in Devon.*

(OS Landranger Map 201, Plymouth and Launceston Grid ref: 46,64).
Modelling the locality to be visited on the fieldtrip

"In the classroom the concept of contours should always be taught with the aid of models when children are at the stage of concrete operational thinking."

(Boardman 1983 p. 60.)

In previous work, the children had already experimented with slicing up clay models of hills and valleys and drawing around the slices to generate contour line maps so they had some elementary understanding of how contour lines indicate landshape, (see plates 1-3). They were aware that "the closer the lines the steeper the slope" and that the contour numbers indicated height and which way the land was rising or falling.

![Image of children working on contour maps from clay models.]

**Plates 1-3: The Children’s earlier work on generating contour maps from slicing up model clay hills**

To develop these ideas further, the children began constructing a 3D model from the OS map. A section of the OS map was enlarged in colour. This made it easier to read the contour lines which can be very feint if photocopied in black and white from the...
original map. I then traced over the contour lines with a dark brown pen to accentuate them and to make it possible for black and white copies to be made. The children each took a copy and glued their cut-out onto a piece of 5mm styrofoam mounting board (a much cheaper option is to use corrugated cardboard from boxes). The boards gave a convenient arbitrary unit for the interval between each contour line. Although this resulted in some degree of distortion in the vertical scale, the advantages of using an easily replicated layer of material outweighed this disadvantage. However, if for practical reasons vertical exaggeration is unavoidable, then it is important to keep it to a minimum to avoid misleading distortions.

"The whole purpose of building a relief model is to help children visualise the landscape from the contour map. For this reason, care should be taken to avoid excessive exaggeration of relief which occurs if very thick tiles or other layers of material are used in the model. Vertical exaggeration is rarely given adequate attention in model building with the result that children may easily develop a distorted impression of the landscape."

(Boardman 1993 p. 64.)

Boardman goes on to suggest a maximum level of exaggeration which will avoid major distortions of the landscape occurring.

"If card 1mm thick is used to represent each 10m in height, there will be no vertical exaggeration. In practice this would be insufficient to bring out the differences between the lower and the highest parts of an area of gentle relief. If the difference in height is 100m, the model would be only 1cm high. Thus it is generally advisable to use thicker material. If card 2mm thick is used to represent each 10m in height, for example, the vertical exaggeration is x 2. Similarly 3mm to 10m gives a vertical exaggeration of x 3, 4mm gives x 4 and 5mm gives x 5. The latter is usually regarded as the maximum desirable if distorted impressions of landscape are to be avoided."

(Boardman 1983 p. 4)

Although the children were using 5mm board, the original map had been enlarged by 400% so distortion was less than x 2.

Working in pairs, the children then cut around their chosen contour line mounted on the styrofoam board. The easiest tool for the children to use in this task was a key-hole saw which has a hacksaw blade projecting from a sturdy handle, (see plate 4a & 4b).

Plate 4a:
Example of a key-hole saw. It is accepted practice for hacksaws to be readily used in Primary DT. The blades of a key-hole saw and a hacksaw are the same the only difference is that the key-hole saw has no metal arch over the blade. This gives the
appearance of a knife but has a squared-off end. However, if safety rules are stressed, there is no reason why the key-hole saw should not be used by older primary children less safely than a hacksaw.

Plate 4b: A child using a key-hole saw to cut around a contour line on the mounted map.

The children assembled the 'contour layers' and glued them together using PVA glue. This is an easy exercise as the contour lines themselves help with the alignment of each layer, (see plates 5 & 6). The assembling of the model is a much quicker and smoother operation if all the pairs of children glue the back of their layer at the same time so that they are all ready for assembly. The children can then sit in a circle and fetch their respective layers in turn from their tables and the model will grow very quickly in front of their eyes without prolonged delays for the gluing of each layer.

They then examined the route their fieldtrip would take and began to interpret the black chevron lines across the road on the map by relating them to the steep gradient on the model where the road descended to the river, (see plates 7 & 8). The children deduced that the number of arrows indicated the steepness of the hill. (one arrow indicates a gradient of 1 in 7 to 1 in 5 and two arrows a gradient of 1 in 5 or steeper). These ratios were to be explored later on the fieldtrip by firstly the kinaesthetic experience of walking up and down the hills, secondly, sketching the road warning signs and thirdly, modelling and mathematically constructing different slopes back in the classroom.

When the children viewed the model from the side they, in effect, experienced a cross-section of the landscape.
"A model is valuable in helping pupils to understand the concept of a cross section, which is most easily described as a slice through the landscape. The side of a relief model is, in effect, a section across the landscape."

(Boardman 1983 p. 65.)

**Plates 5 & 6:** A group of children assembling the 'contour layers' of their model.
Plate 7: Children with their model of an area close to their school, pinpointing the 1:4 hill they are going to visit on their fieldtrip to Gnatham on the River Tavy.

Plate 8: The children identifying the 1:7 and 1:4 hills on their mapping model of the Bere Penninsula. One chevron means the gradient is 1:5 to 1:7 Two chevrons means the gradient is 1:5 or steeper.
The fieldtrip with map and model

The children were taken on the fieldtrip in cars. On the outward journey, one group of children navigated with the map and the other with the model. They were delighted to find the model echoing even the slightest change in the incline of the road. Their fingers became the car, kinaesthetically tracing the route and mimicking its movement as it ascended and descended. This exercise also helped with map orientation skills as the model had to be turned to "face the way we were going". The children got out of the vehicles at intervals with their model to make field observations and to take sitings of elevations and inclines in both the environment and on the model, (see plate 9).

Plate 9: Children with their OS map and relief model visually and kinaesthetically experiencing a 1: 4 hill on the road to Gnatham.

Field sketches of the road warning signs for "steep hill"

During the fieldtrip the children stopped to make sketches of the road signs they saw, (see plates 10, 11, 12). Some of these indicated gradient as a ratio e.g. 1 : 4 and some as a percentage e.g. 20%, (see fig. 2) The children were encouraged to ask questions:

- What do the numbers on the road signs mean?
- How is the steepness of a hill measured?
- Can we model some hills we have seen back in the classroom so we can see what they look like and compare them?
Plate 10: A group of children making a field sketch of the warning road sign at the top of a 1:4 hill near their school. This sketch was later used as a reference for making a model road sign to put on their 1:4 clay slope back in the classroom.
Plate 11: A group of children gathered around a road warning sign at the top of a hill with a 20% gradient. Back in the classroom it was this hill that was used to illustrate equivalents between percentages and ratios e.g. 20% = 1:5.
Gradients on road warning signs may be shown as a ratio or percentage

\[
\begin{align*}
\text{Steep hill upwards expressed as a ratio} & = \text{Steep hill upwards expressed as a percentage} \\
1:4 & = 25% \\
\text{Steep hill downwards expressed as a ratio} & = \text{Steep hill downwards expressed as a percentage} \\
1:5 & = 20%
\end{align*}
\]

Fig 2: Some of the warning road signs and gradients visited by the children on a fieldtrip in the locality of their school.

Plate 12: Children sketching the 1:4 road sign on their fieldtrip
Relating gradient to land use.

The children were encouraged during their fieldtrip and map work activities to deduce why areas of mixed woodland appeared in particular locations on their OS map of the Bere Peninsula, (see plate 13). These tended to occur along the sides of stream and river valleys. The rest of the peninsula is covered by farmland belonging to numerous dairy and arable farms such as Hole & Well Farm. The children offered several explanations:-

"The trees grow near the rivers because they get more water".
"The trees are planted to stop the valleys eroding".
"The contour lines are close together so it's steep ........ you can't farm the fields, it's too steep here".

The latter response from one observant child stimulated a flurry of discussion as the children began to check all the patches of woodland on the map and model to see if they only occurred where the contour lines were closely packed. This proved to be the case. To reinforce this observation, the children were given a tiny toy tractor and tried 'driving' it on different parts of the three-dimensional model of the peninsula. On the steeply wooded slopes, the tractor rolled over into the river or stream! (see plate 14 & 15). They also walked up the tributary's valley with their model to see if the valley sides were indeed as steep as the model indicated, (see plate 13).

Plate 13: Children on a fieldtrip relating their model and map to the steeply wooded sides of a valley at Gnatham on the Bere Peninsula.
Plate 14: The children ‘driving’ the tractor across steep slopes on their 3D model of the Bere Peninsula to see if it could cope with the gradient.

Plate 15: The children relating the spacing between contour lines on the map to land use. Areas with closely packed contour lines are impossible for the model tractor to negotiate and hence are not farmed but left instead as natural woodland.
Modelling gradients

Back in the classroom, modelling gradients provided the opportunity for integrating mathematics and geography. Understanding gradient involves the mathematical concepts of ratio, percentage, height, length and shape.

These were explored in two ways:
- modelling gradients as ratios using clay
- modelling gradients as percentages using metre rulers and shirring elastic.

The mathematical investigation, in turn, can contribute to the understanding of such geographical ideas as land use, map interpretation and routes.

Modelling gradients as ratios using clay

The children were given wooden right angle triangles with different base to height ratios and asked to measure and discuss their dimensions. To accentuate these ratios, the children used the arbitrary unit of a pencil (cut exactly to 10 cms in length) to measure the bases and heights. Every triangle was made with one side being an arbitrary unit of one pencil length and another side exact multiples of the same pencil. The triangles were all arranged vertically on a table with the side measuring one pencil length as the height. Using a toy car, the children explored the relationship between 'along and up'. On a 1 : 4 triangle, for every 4 units the car travels along horizontally, it has climbed 1 unit vertically, (see plate 16).

Plate 16: Children using the wooden triangles and toy cars to explore the ratios between horizontal and vertical travel.
To make clay models of different gradients, the children pressed a matching pair of triangles against the opposite sides of a lump of clay. These guided a length of fishing line as it sliced the clay into a wedge with the same height and base as the triangles themselves, (see plate 17).

Plate 17: Children slicing a lump of clay into a slope using wooden triangles pressed against the side of the clay as a guide for the fishing line cutter.

The children could run a toy car down the different slopes to observe the effect of gradient on speed of descent. This was not measurable on the small clay models but could easily be extended into a science investigation using a larger tilt board. However, it was possible to explore the issue of gradient and its effect on land use. By placing a toy tractor in a position **traversing** the clay slopes, the children discovered on which gradients it became unstable and toppled over, (see plate 18 & 19). This led to a discussion of why farmers did not plough steeply sloping land for arable or cereal production and the identification of such areas on a local map. Some humorous comments were also made about the problems dairy cows would have "rolling down the hill!"

The wooden triangles were removed from the wedges of clay and the slopes sliced into horizontal layers using lengths of wood 2 centimetres in depth as units of height. Each slice was drawn around with a brown felt to create a configuration of contour lines, (see plate 20). The children placed both the clay slopes and their corresponding contour patterns in ascending order. This highlighted the relationship between the increasing gradient and the decreasing space between the contours. The children used their fieldwork sketches as reference in making an appropriate warning road sign for each clay hill, expressing its gradient as a ratio, (see plate 21).
Plate 18: Children traversing a 1:1 clay slope with a toy tractor and finding that it rolls over.

Plate 19: The toy tractor on a 1:2 slope, unstable and beginning to topple.
Plate 20: A group of children slicing a 1:1 clay slope at 2cm intervals and drawing around each slice to generate a contour line map of their slope.

Plate 21: Clay slopes and the contour line patterns they have generated. Each slope has been labelled with a warning road sign denoting its gradient.
An extension to work on gradients and their corresponding contour line patterns is to model convex and concave slopes in clay. If children slice them into horizontal layers, they can compare the configuration of contour lines they generate, (see fig. 3).

**Fig: 3** Convex and concave slopes can be modelled in clay and then sliced horizontally for generating patterns of contour lines for analysis and comparison.

**Modelling gradients as percentages using metre rulers and elastic.**

To develop children's skills in measuring and expressing gradients as percentages, metre rulers were used. A metre ruler laid flat on the ground gives a convenient horizontal distance of 100 units (cms) and another ruler held upright at one end gives a selection of the same units for vertical climb. A length of shirring elastic can be used to link the two rulers for example, a triangle formed in this way with a 100cm base and 20cm height has a 20% gradient. This means that a toy car would climb 20cms vertically for every 100cms it travels horizontally. 20 units out of every 100 = 20%, (see plate 22).

Using the same triangle, it is also possible to translate percentages into ratios and vice versa. If the child travels 4cms along the horizontal ruler with a toy car and then measures up vertically from this point to the elastic slope, the height will be 1cm, (see plate 23). This is a 1: 4 triangle. These ratios can be multiplied eg:

<table>
<thead>
<tr>
<th>Along Grey</th>
<th>Up Grey</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 cms</td>
<td>2 cms</td>
</tr>
<tr>
<td>12 cms</td>
<td>3 cms</td>
</tr>
<tr>
<td>16 cms</td>
<td>4 cms</td>
</tr>
<tr>
<td>100 cms</td>
<td>20 cms (20%)</td>
</tr>
</tbody>
</table>

The children recorded their investigations on graph paper, (see fig. 4 & plates 24 & 25). The more able mathematicians calculated all the fraction equivalents in converting a percentage to a ratio, (see plate 25). This helped them to see the
relationship between numerators and denominators and insights into the process of cancellation.

**Plate 22:** A group of children using two metre rulers and a piece of shirring elastic to create gradients as percentages.

**Plate 23:** The children using a third metre ruler to convert a 20\% gradient into the ratio of 1:5.
Fig. 4: Children's' written and graphical recording of gradients as percentages and ratios.
Plate 24: A child illustrating a 15% hill on graph paper

Plate 25: A child illustrating the equivalence of a 20% and 1:5 hill through fraction patterns.
Modelling water catchment

The children covered their model of the Bere Peninsula with baco foil by forming it around the relief features, (see plate 26). They then coated the foil with layers of papier mache, (see plate 27). This smoothed out the terracing effect created by the layers of styrofoam board.

"It is most important that the model is not left in this form because the stepped or terraced appearance bears no resemblance to the real landscape".

(Boardman 1983 p. 64.)

Plate 26: Children, covering the model with baco foil

When the papier mache was dry it could be lifted off like a shell and superimposed back onto the model to illustrate how continuous slopes related to the contour lines and layers of the model underneath, (see plate 28).
Plate 27: Children, coating the foil with layers of papier mache.

Plate 28: The dried papier mache landscape lifted off and laid alongside the layered relief model and the original colour enlargement of the map.
After applying a coat of varnish to the papier mache to waterproof it, rainfall was simulated using a watering can. The children were able to observe and discuss the water 'run off' and catchment. It was noticeable that the water collecting in the young V-shaped valley flowed more rapidly because of the steep gradients than in the older meandering valley of the River Tavy, (see plate 29).

Plate 29: The children using a watering can to simulate rainfall on their papier mache relief. The River Tavy valley on the model has filled with water and has continued its pathway to the sea across the playground!

It was found that a watering can produced too much of a deluge for the scale of the model, making it difficult to watch the watershed, catchment and confluence in a river basin. In later case studies, it was found that using plant sprayers was more successful as the rain formed a finer mist and slowed down the process of runoff. The watershed around a river basin can be identified by using a marble to simulate a raindrop and marked out by the children using a water-soluble OHP pen.

The children were set the challenge of finding the highest points around the river from which the marble would roll ("drain / run") down into the river and its tributaries. They marked these points with a broad, blue water-soluble overhead projector pen. (see plates 30 & 31). These marks eventually created an enclosing ring around the river system. If the marble was placed anywhere inside this ring, it rolled into the river. If it was placed anywhere outside the ring, it rolled into another river system. The ring defined the watershed, the place on high ground around a river where the water is shed like a parting in someone's hair. The area within that ring is the catchment area for the river. The water sprayers simulate the rain and the blue pen ink begins to run into the river valleys, illustrating runoff, tributaries and confluence, (see plates 32 & 33).
Plates 30 & 31: A group of 9-10-year-old children using marbles to identify the watershed around a river
Plate 32: A group of children are using plant sprayers to "rain" on the model. The dye from the pen marks around the watershed is running into the channels of the Cherry Brook River and its tributaries.
What distance will we travel?

"Understanding scale expressed as a statement (such as 1 cm stands for 1 km) depends on a clear understanding of what those units look like in the real world. One centimetre is easily demonstrated but it is important for the children to be aware of how far a kilometre is in their own locality; for example, 'from the school to the swimming baths'."

(Wiegand 1993 p.50.)

The children were set the challenge of calculating the distance they would be travelling on their round trip from the school, down the steep hill to the River Tavy and back. On the enlarged section of an OS map, they plotted the route using string, (see plate 34).

"Curved distances can be measured by using a piece of thin string and then holding it against the scale line. This is surprisingly difficult to do, however (the string won't always behave when laid along the roads, etc. on the map)."

(Wiegand 1993 p. 50.)

To overcome the problem of 'disobedient' string identified by Wiegand (1993), the children came up with the idea of using blu tac to hold it in place. This would be a very fiddly exercise for primary children if they were restricted to the original map itself. By using a colour enlargement of both map and scale, it not only makes the
map more legible for young children but also allows the accurate following and measurement of a route with string. When the children lifted the string from the map, they laid it along the scale marked in miles and kilometres, (see plate 35). The distances were recorded and taken with them on the fieldtrip for comparison with the reading on the car's mileometer.

The distance calculated by the children : 4.7 miles
The distance recorded on the car mileometer : 5.0 miles

This raised the question of why there was a discrepancy of 0.3 miles. One child thought that they had not measured accurately enough but several others were quick to suggest that the map was "flat" and "did not go up and down" as they did on the journey. On their own initiative, they measured the distance with string and blu tac again but this time over the relief model, (see plate 36). The measurement came out at 4.95 miles. They had discovered most of the missing 0.3 of a mile! By using a 3D model of a locality alongside a map facilitates the understanding that map distance cannot take into account the relief of the landscape. The activity also provided opportunities for the me to revise the notation of fractions and decimals in a relevant context for those children needing the reinforcement.
Plate 34: Two children marking out the route to be taken during their fieldtrip by using string and blu tac

Plate 35: Laying the string along the map scale to calculate the distance in miles and kilometers.
Plate 36: The children using string and blu tac on their relief model to calculate the distance travelled during the fieldtrip. The piece of string on the model was longer than the piece on the map because it had to negotiate the rise and fall of the terrain.

Using blu tac and string is an effective but rather time-consuming method of calculating distance from a map so the author initiated a search for alternatives. The children came up with ideas of using strips of cardboard half a mile or kilometre in length or estimating with finger widths.

"...it may be simpler to use a map measurer (sometimes called an opisometer). This is a small device which is wheeled across a map and the distance travelled can be read off on a scale on the side of the instrument. Because they are often made for maps at a variety of scales, however, reading off the distance can be tricky."

(Wiegand 1993 pp. 50, 51.)

Bearing this problem in mind, I introduced the notion of trundle wheels, used by children in schools and by the Highways Department out on the road. Then the challenge of "could a trundle wheel be miniaturised?" was set. Some children chose to make a trundle wheel to record in miles, others in kilometres. They found that a strip of cardboard or paper laid along the map scale could be marked off in tenths of a mile or kilometre and was more effective than string in forming a circle because it could be rolled into a tube. The latter was traced around on a piece of stiff cardboard and each interval of a tenth marked. When the circle was cut out and a drawing pin pushed through its centre, it could be fixed to a wooden stick, completing the miniature trundle wheel, (see plate 37). They proved extremely effective, even though the circles had some slight irregularities! When the wheels were tested on the scale, the children were elated to find a precise match, (see plate 38). The blu tac and string method and the 'trundle wheels' came within 0.1 of a mile of each other when
the children applied them to the map itself, (see plate 39). One slight problem encountered was occasional slipping of the wheels caused by the covering of tacky-back plastic that they had been applied to the map for protection.

Finally, the children were introduced to the idea of measuring distances on a map using a pair of dividers set at a prescribed interval and walking them along a route, (see plate 40).

Plate 37: Two children making their miniature trundle wheel.

Plate 38: Testing the miniature trundle wheel for accuracy by rolling it along the map scale.
Plate 39: The children 'trundling' the route taken on their fieldtrip using their miniature trundle wheel.

Plate 40: Children using a pair of dividers to calculate distances along a route on the enlarged map.
Evaluation

"Fieldwork, like assessment, is not a bolt-on accessory, it must be an integral part of planning for National Curriculum Geography."

Foley & Janikoun, J. (1992 p.53.)

In evaluating this project, it quickly became clear that the combination of fieldwork, mapping and modelling in the immediate locality was a stimulating 'cocktail'. The children's motivation levels were extremely high. The excitement and sense of wonder that this generated was, for me, one of the greatest delights of the project. The gradients and road signs in the local environment provided a meaningful, relevant and real life context for engaging with the numeracy of ratios and percentages.

"Fieldwork offers the opportunity for interesting and innovative teaching and learning; we need to make the most of it to bring a real practical dimension to our pupils' geographical experience. We should remember that, for many children, a fieldwork visit may be one of the most exciting and memorable events of their lives."


The combination of fieldwork and surrogate model environments also proved to be a powerful tool in accelerating the children’s learning.

"The argument for fieldwork has been dramatically strengthened in the past few years by neurological studies of the brain. We learn best, it seems, from rich, multi-sensory environments that provide a range of messages and meanings. Our brains are particularly good at extracting patterns from real life situations where information comes in a variety of modes and there is immediate feedback."

Scoffham (2000 p.17.)

Their understanding of contour lines, map symbols and scale were greatly enhanced. The models greatest strength was in bringing the map to life and giving the children an overview of the landscape not possible from the ground.

"During the construction of this type of model the concept of contour lines is obviously brought out and the flat map is literally brought to life."

(Rowbotham 1988 p.158.)

The combination of fieldtrip and map alone would not have offered the same stimulus and learning opportunities. The Piagetian Modelling geographical features and processes helps to make difficult abstract concepts concrete and tangible to primary children.

"Properly introduced, models do help children to appreciate the reality they are studying, giving greater precision to their learning and providing a sense of achievement if the product is finished well. They provide a chance for other skills to be demonstrated while the various geographical concepts of scale, form, function and distribution can be demonstrated and reinforced depending on the type and purpose of the model."

(Rowbotham 1988 p. 157.)
References

Scoffham (2000) 'Fieldwork that is right up your street ', in *TES Curriculum Special*, p. 17. London: TES.

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Photographs: © Photographer - Steve Pratchett

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PHOTOGRAPHS:

**Film 1 Negative numbers**

28A p. 62 ratio triangles
24A p.63 slicing clay slope
16A p.64 tractor rolls down 1:1 slope
17A p.64 tractor traversing 1:2 slope
10A p.65 clay slopes with signposts and contour maps of each slope
15A p.65 slicing the clay
32A p.67 ratio board
34A p.60 children sketch 1:4 signpost on fieldtrip
29A p.69 children drawing ratio hill 1:4

**Film 20 negative numbers**

17A p.58 group posing with Bere Peninsula model
10A p.59 children with model on hill next to car
0A p.60b children sketch signpost at 20% hill
15A p.71 miniature tractor rolls down slope on the map model
14A p.70  map and model laid next to each other
6A p.70  children on fieldtrip with model in the valley
34A p... assembling layers of the model
36a p... cutting along contour lines

Film 21 Negative numbers

4/4A p.76  children laying string off against map scale
5 p.76  string being laid along road on map

Film 14 negative numbers

22a p.79  using dividers on the map
18A p.73  map next to model next to papier mache shell

Film 22 negative numbers

21A p.67  children converting ratio to % on board
18A p.72  covering model with baco foil
17A p.73  coating baco foil with papier mache
3A p.74  watering papier mache shell with watering can
23a p.69  child working out % & ratio fractions
12A p.78  making a trundle wheel
11A p.78  testing trundle wheel on map scale
10A p.79  testing trundle wheel on map
1A p.77  children applying string to map