The Use of 'Diagnostic Probes' to Aid Teaching and Learning in Science

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Aim

To discover if the use of diagnostic probes can increase teacher effectiveness and pupil learning in Science.

Dimensions of this Case Study

This study was carried out with 200 pupils in 10 classes in our school. The pupils used in the study were mainly from years 7, 8 and 9. Pupils in Science are taught in mixed ability, mixed gender groups in years 7 and 8. Pupils are grouped by ability in year 9 but sample groups used were taken from the whole ability range.

Summary of Findings for this Case Study

- Diagnostic probes when used to find out about children's understanding of a topic prior to and during teaching can provide essential information for teachers in their short-term lesson planning and longer term development and review.
- These diagnostic methods can be used to inform teachers about the development of children's understanding and as a tool to evaluate their own teaching.
- Children's levels of understanding depended not only on the difficulty of the concept but also on the context in which it is applied.
- Diagnostic probes can take many forms and can be integrated into existing teaching schemes easily.
- Active research using diagnostic methods in the science laboratory can motivate and enhance the learning of pupils by helping them focus more clearly on the learning outcomes.
- Active research of children's learning can motivate teachers and help them focus more clearly on their teaching objectives.
- The use of diagnostic probes has led to the development of 'learning grids' as a way of analysing science teaching.
- Learning grids could contribute to teachers' planning, assessment and target setting in science.

Introduction

Pupils arrive in science lessons with existing ideas about the natural phenomena which are to be studied. The aim of this work was to investigate how diagnostic probes might be used to uncover these existing ideas; to identify the role which diagnostic probes could have in the teaching and learning of science and if their use would lead to increased effectiveness of teaching.

What are Diagnostic Probes?

A range of methods have been used in identifying pupils' understanding of scientific concepts – interviews, concept maps, children's writing, games, conflict situations and pencil and paper tests. However they have their limitations – for many, time can be a prime factor. It was therefore our aim to develop a series of probes which could be used by teachers in our school to assist them in their planning. The probes would, therefore, not only have to be successful in identifying pupils' levels of understanding within an area of science but they would also have to become an unobtrusive part of teaching. Through their use we were trying to create an approach which would lead to more effective teaching by focusing on what the pupils already know and understand.

Development of the Probes

Three areas of the science curriculum were chosen for investigation – one from each of Science 2, 3 and 4. In this way we would provide an opportunity for as many of the department to become involved in the trialing and development of the probes as possible. The three areas of the science curriculum chosen for investigation were:

- Inheritance
- Burning
- The Earth in Space and Gravity.

Research was reviewed on children's understanding in Science and this was used as the basis for the development of the probes. This research review identified possible categories of ideas which pupils have, which could then be investigated by our probes.

In each of the areas chosen probes were developed and trialed with a small group of pupils. The results of these tests were then analysed and compared to the findings of previous research. The categories identified by the probes were then used to further refine the probes prior to their use with the main test groups of pupils.

In each of the following sections a brief account is given of the review of research into pupils' ideas followed by a description of the probes developed and, finally, the results obtained.

Inheritance

The review of research revealed that the following ideas were held by pupils:

- Some features are inherited from parents.
- Humans are more unique than similar, i.e. we are all different from our parents and each other.
- Boys inherit more things from their fathers than girls and vice versa.
- Different organisms inherit features to different degrees. Humans inherit many of their features, then mammals, then other animals, but plants inherit only to a small extent.
- Acquired characteristics are inherited particularly if the feature has been present for a long time in the parent or it has been present over several generations.
- Children have poorly formed ideas about the purpose of sexual reproduction.

The following three probes were created:

Features – In this probe the pupils were asked to sort pictures of inherited and acquired characteristics in humans, mammals, invertebrates and flowering plants, into those they believed would be inherited and those that would not. This was used to measure the extent to which the nature of the organism influences children's beliefs about inheritance.

People – Pupils were asked to predict the likely appearance of the son and daughter of a couple whose features differed in three ways.
This was used to see if pupils think inheritance is gender linked in humans.

Puppies – Pupils were provided with a picture of a dog and were asked to predict which of three features could be passed onto its puppies. Two of its features were labelled as having been acquired since

birth. This was used to find out what sort of features pupils thought could be passed between parents and offspring.

Our findings were consistent with previous research, with the following ideas being of most interest:

- There was little disagreement between pupils about which features would or would not be inherited by humans. There was less agreement about inheritance in plants and invertebrates. Therefore using pea plants and fruit flies would not be a helpful context for introductory lessons on inheritance.
- The majority of pupils believe that features such as height and hair colour are sex linked – parents pass features onto a child of the same sex. Other features such as short sight can be a blending of the parents' influence.
- Pupils believe that features influence genes as well as vice versa. The earlier a feature was acquired in the life of an animal, the greater its chance of being passed on to the next generation.

Burning

The review of research revealed that the following ideas were held by pupils:

- When fuels burn they contain energy, or they are the energy.
- When fuels burn they pass on energy and turn into waste.
- Burning is a destructive process in which waste is produced.
- Burning is not a chemical reaction, simply a transformation of properties of a substance.
- Great confusion exists about the role of oxygen in combustion.

The following five probes were created:

Burning – The probe took the form of a card sort. This was used to identify the possible links which pupils made between terms involved in burning which included – e.g. energy, heat, ash, smoke, etc.

Burn, melt and evaporate – Pupils were asked to complete a grid to say if a substance burned, melted or evaporated when it was involved in combustion. This was used to see if pupils could distinguish between burning and changes of state.

Candles – The pupils were asked to predict the time a candle would burn in different gases – this was done both as a practical activity and as a paper exercise. This was intended to probe pupils' understandings of the role of oxygen in burning.

Modeling – Pupils were asked to arrange paper discs to show how particles combine upon combustion. This was used to probe pupils' understandings of the way in which combustible materials combine with oxygen.

Mass – Pupils observed burning materials and were asked to predict and explain any changes in mass. This was used to find out the ideas that pupils have regarding conservation of mass during burning.

Our findings were consistent with previous research, with the following ideas being of most interest:

- Their level of understanding of the process depends upon their familiarity with the substance being burnt.
- Pupils have an awareness that oxygen is involved in burning but have no preconceived ideas about its role.
- Pupils confuse burning and melting when dealing with wax. They also confuse burning and evaporation when dealing with liquids. These misconceptions influenced the pupils' ideas about conservation of mass during burning.

The Earth in Space and Gravity

The review of research revealed that the following ideas were held by pupils:

- There was a clear pattern of development in pupils' ideas from a flat earth to a spherical model.
- Gravity pulls objects down – this may be in conflict with the idea of pulling towards the centre of mass.
- Gravity does not exist in space.
- The universe takes the form of a sphere made of all the other objects lying outside the solar system.
- Great confusion exists regarding the sizes and distances of objects in the universe.

The following five probes were created:

Models – The probe involved the use of a range of different sized balls to probe the problems children have with scale in the universe – in particular the solar system.

Order – This involved the use of a card sort in which pupils were asked to sequence bodies (e.g. sun,

galaxy, solar system, etc.) in order of size. This was used to identify the ideas pupils have about the orders of size of bodies and systems in the universe.

Solar system – This involved the use of a card activity in which pupils could choose bodies (e.g. star, planet, comet, galaxy, milky way, etc.) that they would find in our solar system. This was used to identify what pupils believe the solar system is.

Gravity – Ball – Pupils were provided with a diagram and asked to explain what would happen when a ball was released in different places. This was intended to identify the ideas that pupils have about why objects fall.

Gravity – Objects – The pupils were provided with a diagram on which different objects were shown and they were asked to explain what would happen when the objects were released. This was used to identify the ideas that pupils have about the effect of gravity on different objects.

Our findings were consistent with previous research, with the following ideas being of most interest:

- Scale is a major problem for pupils when thinking about the universe. Three dimensional models are even harder for pupils to use than two dimensional diagrams.
- Many pupils believe that the solar system is the largest system in the 'universe' and believed that galaxies and other stars would be found in our solar system.
- The majority of pupils do not associate 'falling' under gravity with mass but are confident with the idea that heavy objects will fall but light objects will not.
- The majority of pupils believe that gravity does not exist in space. They will change their ideas of falling to meet the context in which it is considered – a ball will fall on earth but will not fall on the moon.

Diagnostic Probes and their Place in Teaching

It is clear that the probes did allow us to explore the range of ideas that pupils held in each of the areas under investigation. However, the probes will need further refinement in order that they can be used fully as part of our teaching schemes.

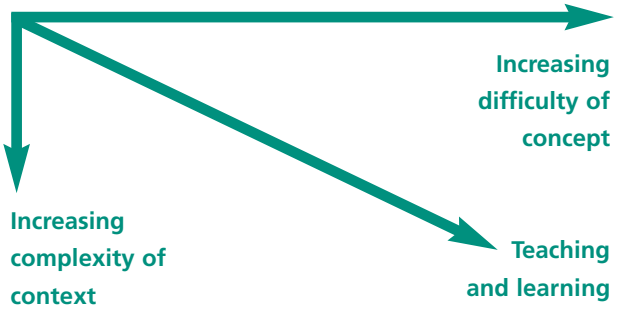
Through our work it became clear that we had identified three possible types of probe:

- **Baseline** – to identify pupils' initial understanding prior to teaching.
- **Formative –** to diagnose pupil understanding, stimulate thought/interest, to challenge ideas during the course of teaching.
- **Summative** – to evaluate pupil understanding and teaching in comparison to learning goals.

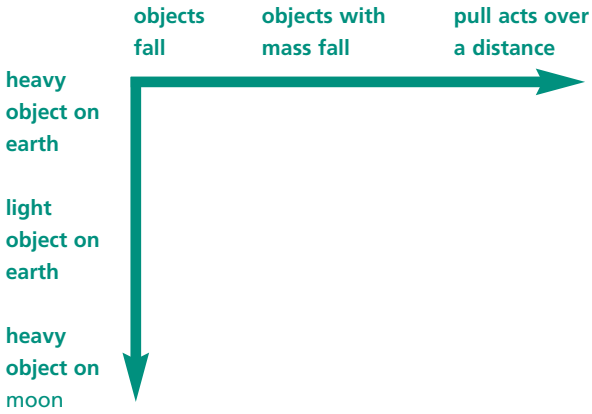
Therefore the probes could be used as an analytical tool such that we could respond in our teaching. They also provided an excellent vehicle for dialogue between teacher and pupil.

It was clear from our work that the responses of pupils depended not only on the complexity of the idea but also on the context in which it was applied. This led to us developing the idea of a 'learning grid'.

The learning grid is an attempt to show the relationship between the difficulty of the conceptual idea and the complexity of the context in which it is applied.



It could therefore be used to identify a possible learning route through a topic by recognizing that the pupil has to go through some significant steps in learning. The following shows a possible early attempt at producing such a learning grid with identified significant steps in learning.



It is therefore our aim to identify probes which could be used to access each area of the grid, thus allowing the use of increasingly difficult probes with different groups of pupils to develop the idea further. This grid would therefore take an area of science and follow its development from the simple ideas, possibly at KS1and KS2, through to the more complex ideas leading to GCSE and 'A' level.

Learning grids can be used by staff to identify the way in which certain contexts may deny access to learning for some pupils. Through this they will plan better their approach to a topic and become more effective. It will also enable staff to identify the position of a pupil more clearly within the learning route and help staff to set more realistic targets for them.

Our ideas on the use of diagnostic probes stemmed from the elements of good practice in science teaching which uses the ideas that pupils have as a starting point for teaching. However, as our study progressed, it became clear that the use and purpose of the diagnostic probes changed. We have recognized that the diagnostic probes developed could now be used for many important purposes such as:

- prior to teaching a topic to measure initial understanding;
- during teaching as a learning activity to challenge and stimulate thought;
- at the end of teaching of a topic to evaluate teaching;
- to inform other colleagues of the ideas that children may hold about a topic;
- to assist teachers to review and develop schemes of work;
- to assist teachers in target setting for individuals and groups of pupils;
- to challenge teachers' own thinking and understanding;
- to stimulate and motivate teachers through being more effective.

Further Reading

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