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4 The right question at the right time

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A child was reflecting sunlight onto the wall with a mirror. The teacher asked: 'Why does the mirror reflect sunlight? ' The child had no way of knowing, felt bad about it and learned nothing. Had the teacher asked, 'What do you get when you stand twice as far away from the wall?' the child would have responded by doing just that, and would have seen his answer reflected on the wall.

Another teacher took his class to explore the surroundings. They came to a flowerbed with what he called 'four o' clock flowers". He asked: 'Why do these flowers close in the early evening and open again in the morning?' Nobody, including the teacher, knew. The question came from the 'testing reflex' that we all struggle with. He could have asked: 'Would the same flower that closes at night open again the next morning?' And the children could have labeled some flowers and found out the answers.

I once witnessed a marvelous science lesson virtually go to ruins. It was a class of young secondary school girls who, for the first time, were let free to handle batteries, bulbs and wires. They were busy incessantly, and there were cries of surprise and delight. Arguments were settled by 'You see?', and problems were solved with, 'Let's try!' Hardly a thinkable combination of batteries, bulbs and wires was left untried. Then, in the midst of the hubbub, the teacher clapped her hands and, chalk poised at the blackboard, announced: 'Now, girls, let us summarize what we have learned today. Emmy, what is a battery?' 'Joyce, what is the positive terminal?' 'Lucy, what is the correct way to close a circuit?' And the 'correct' diagram was deftly sketched and labeled, the 'correct' symbols were added, and the 'correct' definitions were scribbled down. And Emmy, Joyce and Lucy and the others deflated audibly into silence and submission, obediently copying the diagram and the summary. What they had done seemed of no importance. The questions were in no way related to their work. The rich experience with the batteries and the other equipment, which would have given them plenty to talk and think about and to question, was in no way used to bring order and system into the information they actually did gather.

These teachers were asking the 'wrong' questions, ones which were unproductive in encouraging the children's learning. But how does the teacher diagnose such a question?

What is a 'wrong question?

Wrong questions tend to begin with such innocent interrogatives as why, how or what. But this is deceptive, for many good questions, too, begin with similar expressions. The real character of wrong questions lies in their 'wordiness'. They are purely verbal questions, which require wordy answers, often neatly dressed in bookish phrases. Generally the answers precede the questions and are to be found in textbooks. They can also be obtained from blackboards and preserved in copybooks. When, therefore, a wordy question is asked, children try to look for the words of the answer and are totally lost when they cannot be found. These questions are not problems to be solved. They draw away from scientific problem solving.

However, recognizing a 'wrong' question is one thing, how to ascertain a 'right' question is quite another. For what is a good question? A good question is the first step toward an answer; is a problem to which there is a solution. A good question is a stimulating question which is an invitation to a closer look, a new experiment or a fresh exercise. The right question leads to where the answer can be found: to the real objects or events under study, there where the solution lies hidden. The right question asks children to show rather than to say the answer: they can go and make sure for themselves. I would like to call such questions 'productive' questions, because they stimulate productive activity. There are productive questions of various sorts. In the course of a scientific study they usually follow a certain pattern, since the 'answerability' of one type of question depends on experience obtained through endeavoring to answer questions of another kind.

Attention-focusing questions
The simplest kind of productive question is the straightforward 'have you seen', or 'do you notice' type of question. These are sometimes indispensable, in order to fix attention on some significant detail which might easily be overlooked. Children frequently take care of these questions themselves by their constant exclamations of 'Look here!' so the teacher need not always bother. Children ask these questions at all times but paricularly at the introduction of new objects of study. The necessary initial exploration of new materials, the 'messing about' and the 'getting to know you' stage of exploration, is very much a 'can you see and do you notice' situation. The 'what?' questions closely follow, of course. 'What is it?' "What does it do?' What does it show about itself?' 'What happens?' "What do I find inside (outside)?' 'What do I see, feel hear?' And simple observation is the route to the first simple answers, followed by more complicated questions.

Measuring and counting questions
Questions such as 'how many?', 'how long?' and 'how often?', are measuring and counting questions to which the children can check their answers themselves. They can use new skills; learn to use new instruments, and feel confident, for no teacher can challenge your measuring ruler. There are many situations in which these questions arise, and they lead naturally to the next category of questions: comparison questions. 'Is it longer, stronger, heavier, more?' These are comparison questions and there are many ways of phrasing them. Often they are preceded by 'how much?' which adds a quantitative aspect and necessitates greater accuracy.

Comparison questions
Other, more qualitative, comparison questions bring about sharper observation. For instance: 'In how many ways are your seeds alike and how do they differ?' Things can differ in many respects, such as in shape, colour, size, texture, structure, markings and so forth. Carefully phrased comparison questions help children to bring order into chaos and unity in variety. Classifying, attribute games, making identification keys, or making tables of collected data, are disguised comparison questions. These questions logically lead to another class of questions which make the children create a different situation, or environment, so they may expect to obtain a different result.

Action questions
These are the 'what happens if" questions which can always be truthfully answered. They entail simple experimentation and never fail to provide a result. They are productive questions of great value and

particularly appropriate at the beginning of a scientific study to explore the properties of unfamiliar materials, living or non-living, of forces at work, and of small events taking place.

What happens if you place your antlion in damp sand?
What happens if you pinch the seedleaves off a young growing plant?
What happens if you place a cutting or twig in water?
What happens if you put your twig upside-down?
What happens if you hold your magnet near a match?
What happens if you throw a tiny piece of paper in a spider's web?

Innumerable good examples of 'what happens if…' problems can be given which lead to as many solutions that can be readily found to the satisfaction of the children and their teachers.

Working on 'what happens if' problems, children are bound to discover some form of relationship between what they do and the reaction of the thing they handle. This greatly adds to the store of experiences which young children require. As adults, we often assume that children can fill the generalizations and abstractions which we so casually throw around, but children must collect the 'fillings' themselves. An exciting addition to solving 'what happens if' problems is the challenge to predict the outcome. Initially the children will just guess, and find themselves way out in their predictions, but with the accumulation of experiences they become sharper. The ability to predict is a prerequisite to the ability to tackle real or, rather, more complicated problem-solving questions.

Problem-posting questions.
After sufficient activities provoked by the type of questions just described, children become ready for a new type of question: the more sophisticated 'can you find a way to' question. This will always set up a real problem-solving situation to which children enthusiastically respond,, provided it makes sense to them.
I once asked a class of children, 'Can you make your plant grow sideways?' For a short time they had been studying plants growing in tins, posts, boxes and other contraptions made of plastic bags. I was just a little too anxious and too hasty and, quite rightly, I got the answer, 'No, we cannot'. So we patiently continued with scores of 'what happens if' experiments. Plants were placed in wet and dry conditions, in dark and in light corners, in big boxes and in cupboards, inside collars of white and black paper, upside down, on their side, and in various combinations of these. In other words, the children really made it 'difficult and confusing' for the plants. Their plants, however, never failed to respond in one way or another, and slowly the children began to realize that there was a relationship between the plant and its environment which they controlled. Noticing the ways in which the plants responded, the children became aware that they could somehow control the growth of plants in creative ways, because the responses of the plants became evident by the way they grew. Tips curved upwards, stems bent, plants grew tall and thin, or sometimes withered altogether. The children discovered that moisture as well as light and position has an effect upon the growth of plants.

When the question 'Can you find a way to make your plant grow sideways?' reappeared later there was not only a confident reaction, there was also a good variety of attempts, all sensible, all based on newly acquired experience, and all original. Some children laid their plant on its side and rolled a newspaper tube around the container and the plant. Others manufactured a stand to hold a horizontal tube into which they pushed the top of their plant, (this one turned back). One group closed their plant inside a box with a hole, but they fixed a tube in the hole and directed it toward the light of the class window. Some just tied their plant sideways along a cross stick and added restricting strings as soon as the growing tip curled upward again.

It is obvious that 'can you find a way to…' questions must be preceded by a satisfactory exploration of the materials with which the children work. They need to investigate first what possibilities and impossibilities there are, and become familiar with some of the properties of the objects under study particularly those properties which show up in interaction with (things out of0 the environment. Source books and teacher's guides can never indicate when the children are ready for more formal, more complicated, problem solving. This is a matter to be decided either by the children themselves when they spontaneously begin to tackle such problems, or by the sound judgement of the teacher when he has sufficient evidence that the children can move on to more sophisticated activities. This is important to note, for if a teacher rigidly adheres to a (necessarily limited) outline in some textbook, there is a good chance that the children will get confused, and the class ends in chaos.

The 'can you find a way to' question comes in many guises. 'Can you make a mealworm turn around?' 'Can you make a sinking object float?' 'Can you separate salt from water?' It is in essence a prediction question, a more complicated 'what happens if' question turned around. Finding the solution necessitates the forming of a simple hypothesis and consequent verification in a very direct manner. The acknowledgement of the need to recognize variables and to control these emerges naturally. And this is the point where children's science begins to make real progress.

Teachers' how and why questions

Finally there follows a category of questions which we should approach with caution, as there is a serious danger of misusing them. They are, what I call, 'reasoning' questions and they often ask for some sort of explanation. Naturally these questions tend to start with how and why, and that is where the danger lies. The anxious teacher might want to let himself loose in worthy but wordy explanations which will not be rooted in the children's experience. Anxious children might easily mistake them for test questions to which, they often feel; they should have been given model answers. The lack of a model answer make children afraid to be 'wrong'. But 'reasoning' questions are very important in science education and we should never eliminate them. After all, every youngster is a born how and why questioner, so how could we avoid them? What we should eliminate however is the impression that to every question of this sort there is one right answer. Reasoning questions are not meant to be answered in a unique way. They are meant to make children think and reason independently about their own experiences. They are meant to make them reflect upon the relationships they have discovered or recognized, so they can carefully begin to draw conclusions, or make generalizations, on the strength of real evidence that they have collected or uncovered. These questions are intended to open up discussion, to make children freely express what and how they think about their observations and finding. The discussion, the dialogue, the sharing of ideas helps in recognizing new relationships and it aids understanding. It is essential that the children talk freely, that they are not held back by any red light of fear, for even the most preposterous statement can provoke argument, and argument leads to correction, provided it is based on found, and sound evidence.

A child can more easily take responsibility for his answer if the question is presented with the little addition: 'Why, do you think…?' In that case even though there may be something wrong with the thinking, and the opinion may be subjected to fierce argument, the answer to the question will always be right. The child, after all, knows best what he thinks. (The same advice and more is given in Harlen, Darwin and Murphy, 1977.) Care is not only needed in how these questions are phrased, but also in when they are presented. Children who are working with mosquito larvae for the first time may be effectively put off from further exploration and thought by a premature "Why do the larvae come to the surface of the water?' How would they know? They may have framed this question themselves, which is a sign that they do not know, so why ask them?

However, it may well happen that children have watched mosquito larvae wriggle down to the bottom, time after time, whenever they were disturbed by a waving hand, or by a knock on the jar that contained them, or by shaking or stirring the water in which they swam. These children would also see the larvae come up again and again; they might notice their tail tubes sticking up just above the surface of the water. They may time how long the larvae can stay under the water surface. Whenever the larvae come up, the children can discourage them from doing so by shaking the jar, or by knowing the sides of it. And what would the larvae do if you cover the surface of the water with snippets of paper or a sheet of cellophane? The children are bound to become aware of the larvae's persistence to reach the surface. Only after these and similar experiences can the children become involved in a sensible argument when asked, 'Why do you think these larvae come up to the surface of the water?' In the first place, the 'why', here, is easily translated in 'what for'. Secondly, the children can now express their thoughts with confidence, because they have something to think and to talk about, all based on a series of common experiences to which they can refer. They can produce relevant evidence. Within the same frame of reference the teacher can now take part in the discussions as an equal. This is important, for the answer' they come up to breathe' is by no means an obvious one. Many water creatures never come up to breathe, and a tail is not readily associated with the act of breathing. Yet the teacher's contribution may point in the direction of respirational need without it becoming, for the children, an act of faith.

Children's how and why questions

There are a few more aspects of the 'why' question which are useful to consider here. We cannot avoid the question the children ask, and they often ask 'why?'. The erroneous, though flattering, attitude of many parents and children tempts teachers often to bluff their way out with vague, exalted, impressive-sounding 'answers', but this does not help the children. Of course, within their experience they can be given answers which point out relationships, but the experience is not always present. Breaking up the question into manageable 'what happens if' questions and 'let us see how' observations may try the children's patience, but will provide necessary experiences to make understanding possible. In any case, it is good science education.

Nevertheless, real difficulties can arise, for there are many 'why' questions which simply have never been answered yet; others cannot even be answered by science. For instance, questions about why things are as they are lead us rapidly into the realm of metaphysics or theology or mythology. Worthy answers can be obtained, but these are to be found beyond science, and this should be made clear. But also within the bounds of human science there remain many questions yet unanswered and even more to which the humble but honest teacher must admit, 'I do not know'. Well do admit it, for this is a healthy lesson to the children. Science is the search for, rather than the answer to, our questions of why and how. Besides, both 'why' and 'how' are illusive questions. As soon as we approach a satisfying answer, we become aware of a new problem, and a fresh 'why' or 'how' shimmers above the horizon. We have not yet reached the final answer, to a single final 'why?' or 'how?', so the search continues, and it is into this search that we introduce our children. A great number of why-questions are by nature queries of 'what for?', 'to what purpose?' or 'where to?' and these refer to structure-function relationships. Other why questions search for cause-effect relationships, or ask for why things behave the way they do. The teacher's attempt to break these questions up into simpler questions reveals their true nature, and the search for solutions begins to alternate between doing and reasoning.

The simple 'because' reasoned out by the children themselves on the strength of their own evidence and their own experiences are far more valuable and important than any of the reasons provided by adults and faultlessly recited without understanding. Even an adult's understanding depends on his own step-by step progress through masses of experiences, and many of us have understood things, that we were supposed to have learned at school, only years after we were set free to educate ourselves.

Teachers' explanations

Children may be interested in solving problems that are beyond their scope, either because the necessary equipment is inadequate (or not refined enough) or because the required experimentation is simply too difficult or complicated. A knowledgeable teacher is then a great asset and can contribute considerably toward widening the children's horizon of learning and knowledge, because this teacher can fathom the depth of the children's ability and thus measure the quality and quantity of the information or explanation to be given. When children ask, they indicate that they want to know, and when they want to know, they are interested. Interest is a fertile ground in which the teacher's explanation is gratefully and fruitfully accepted. The clever teacher also recognizes that, where questions arise and interest is present, functional literacy shows its worth. Children will be led to good books. Not only will they look for and find an answer to their problem, they will also find that other scientists have grappled with such a problem, and often they may appreciate how much effort and research was required in order to find a solution.

Summary of main points

A question already has within it the kind of answer that can be given, even before it is spoken. There are many different kinds of questions and their varying effect on children is striking. The purpose of teachers questions should be to promote children's activity and reasoning. Questions which do not do this (unproductive questions) are those which ask only about knowledge of words, often for repetition of words given earlier by the teacher or to be found in a book.

Questions which encourage activity (productive questions) come in various kinds and form a hierarchy reflecting the experience of children.

Questions which promote reasoning often start with 'why' or 'how' and can be asked by both teacher and class. It has been suggested that teachers' why questions should include the phrase 'why do *you* think' and should be carefully timed so that children have the necessary experience to form a view which is genuinely their own.

Children's 'why' questions often present problems for a teacher, for not all can be answered and not all should be answered. Some ask about relationships that children can discuss, these can be turned into productive questions (see also Chapter 5). The points emerging so far lead to these guidelines:

Guidelines for 'productive' questions

1. Study the effect on children of asking different kinds of question so that you can distinguish the 'productive' from the 'unproductive'.
2. Use the simplest form of productive question (attention-focusing) during initial exploration to help children take note of details that they might overlook.
3. Use measuring and counting questions to nudge children from purely qualitative observation towards quantitative observation.
4. Use comparison questions to help children order their observations and data.
5. Use action questions to encourage experimentation and the investigation of relationships.
6. Use problem-posing questions when children are capable of setting up for themselves hypotheses and situation to test them.
7. Choose the type of question to suit the children's experience in relation to the particular subject of enquiry.

Guidelines for 'why' and 'how' questions

1. When asking questions to stimulate children's reasoning, make sure they include 'what do you think about' or 'why do you think'.
2. Don't ask questions of this type until children have had the necessary experience they need so that they can reason from evidence.
3. When children ask 'why' questions consider whether they have the experience to understand the answer.
4. Don't be afraid to say you don't know an answer; or that no one knows (if it is a philosophical question).
5. Break up questions whose answers would be too complex into ones that concern relationships the children can find out about and understand.
6. Take children's questions seriously, as an expression of what interests them; even if the questions cannot be answered, don't discourage the asking.