Editorial

The public perception of science (6): The perceptions and conceptions of children
There is a deep ambiguity between 'seeing' as visual perception and 'seeing' as understanding. How seeing and understanding are related was discussed by the Greek philosophers and the questions they raised have remained central for epistemology ever since. Perhaps implications of these questions (if questions can have implications) have not been sufficiently expressed in the theories or practice of education. This opinion may, however, merely reflect my sketchy knowledge of writings on education; but in any case let's look at what such implications might be.

As is well known, Plato held that we know everything at birth, forget most of it, and then—if one is fortunate to have the right education—innate truths become visible. Such truths are mainly principles of logic and mathematics, geometry, and moral precepts of virtue. Plato discusses this in the Socratic Dialogue the Meno. Here Plato reports Socrates as saying:

"Seeing then that the soul is immortal and has been born many times, and has beheld all things both in this world and in the nether realms, she has acquired knowledge of all and everything; so that it is no wonder that she should be able to recollect all that she knew before about virtue and other things. For as all nature is akin, and the soul has learned all things, there is no reason why we should not, by remembering but one single thing—an act which men call learning—discover everything else, if we have courage and faint not in the search; since, it would seem, research and learning are wholly recollection."

Socrates then carries out an experiment to try to test this notion, with a slave boy as subject, on a geometrical problem concerning length of the sides of a square and its area. By questioning the slave boy to arrive at the answer by exposing inconsistencies, Socrates claims that he has not taught but has stimulated his recollection to produce the correct answer—by exposing inconsistencies, which jolted him as by shocks from a torpedo electric fish. But Plato's recollection theory has been more and more difficult to hold with the ever-increasing changes of what is known with advances of science and inventions of technology.

In all discussions relating perception and conception, now as for the Greek philosophers, there is more-or-less explicit ambiguity of 'seeing' with the eye and 'seeing' by understanding of the mind. This might reflect the roles of art and science—which are far more distinctly different now than they were for the Greeks.

A classical example for distinguishing between perceptions and conceptions is 'seeing' a triangle and 'seeing' triangularity. The point being that perceptions are of individual examples, while conceptions are of generalizations. Generalizations may be seen as based on perceptions of many individual examples by induction (which is the basis of Empiricism), or as seen innately by intuition (which is the basis of Idealism) supposedly allowing secure deductions to new cases. Classically, Aristotle represents the former and his teacher Plato the latter view.

The point here is that Aristotle's and also later empiricist accounts stressing experimental discovery and invention have extremely different implications for education from Plato's notion of truths recollected, or known by intuition. In these terms, learning by the experiments and demonstrations of hands-on science is Aristotelian; but what is puzzling is how children move from hands-on experience of examples to brains-on understanding of general principles. This is much the same question as:
"How does science discover general principles?" There are at least two (though not mutually exclusive) accounts. The first is that principles are discovered by flashes of individual intuitive genius; the second that principles emerge when scientific method is applied and the handles turned. This is the account of Francis Bacon, especially in his *Novum Organum* (1620) which set the ground rules for organized science, and for the founding of the Royal Society in the 1660s, by suggesting that science can be a cooperative activity undertaken by many kinds of people, which 'levels men's wits' as truths are discovered by turning the handle of a knowledge-generating machine. How this works was set out in considerable detail by Bacon. His inductive procedures were refined by J S Mill, as 'Mill's methods' (which were constructively criticized by William Stanley Jevons), and refined by Karl Pearson, Ronald Fisher, and many others who developed statistical methods for experiments and testing hypotheses.

Considering how children learn: Do children, if implicitly, apply 'scientific method' to generate their understanding of the world? Jean Piaget (1896–1980), the greatest name in the field, answered "yes". Piaget came to deny Plato's *prior* knowledge of logic (which he sees as necessary for children to learn concepts) in favour of an outright empiricism where logic itself is learned. In *The Child and Reality* (1972) Piaget proposes the following hypothesis (page 94):

"(a) That at every level (including perception and learning), the acquisition of knowledge supposes the beginning of the subject's activities in forms which, at various degrees, prepare logical structures; and (b) therefore that the logical structures already are due to the coordination of the actions themselves and hence are outlined the moment the functioning of the elementary instruments are used to form knowledge."

Piaget follows Helmholtz in saying that inferences are involved in perception itself, (though Piaget prefers the word 'preinferences'). So learning to see, in the perceptual sense, is for him similar to and intimately related with conceptual learning. Piaget offers experiments to show effects of inferences during perceptual development in children, showing that perceptions change as inferences change. For example (*The Child and Reality*, page 95):

"A young child is shown briefly two parallel rows of four coins, one being spaced out more than the other: The subject will then have the impression that the longer row has the more coins."

Piaget goes on to say that joining the corresponding coins of each row by lines, or joining them in other ways, has different effects for different ages or stages of perceptual development. So Piaget suggests that different inferences about the lines are made, each making the rows of coins appear somewhat different. He also cites an experiment from his laboratory in which the numbers 1 and 7 are shown with their tops hidden—and at different orientations. When the 1 is tilted to the slope of the 7, it is still read as a 1 when ending a sequence likely to be a 1; but otherwise it is seen as a 7. So probability affects perception in children.

But how do children 'see' the world conceptually? It is commonly said that children hold magical notions of cause—not distinguishing between their own responses and the behaviour of inanimate objects—and that they hold Aristotelian notions of physics of motion, forces, and so on. Piaget has reported investigations bearing on many such questions, including the famous studies on conservation (or lack of conservation) of matter. In *The Child's Conception of the World* (1929) he describes children as having animistic views, believing that all objects capable of movement, such as bicycles and the sun and the moon, are alive. Piaget finds, in studies carried out with Inhelder, that most children before the age of nine, given various shapes of a lump of clay, do not
appreciate conservation of substance. But how good are adults? A well known marketing trick is to use odd-shaped bottles to make the contents look larger.

A somewhat different approach, and concerning slightly older children, is to be found in a fascinating recent book—*Children's Ideas in Science* (1985)—edited by Rosalind Driver, Edith Guesne, and Andree Tiberghien. This starts with an account by Rosalind Driver of two 11-year old boys in a practical class, measuring the length of a suspended spring as equal weights are added to a scale pan, lengthening it. In the middle of the experiment, one of the boys unlocks the clamp at the top of the spring and moves it up the stalk of the retort stand. He explains:

"This is farther up and gravity is pulling it down harder the farther way. The higher it gets the more effect gravity will have on it because if you just stood over there and someone dropped a pebble on him, it would just sting him, it wouldn't hurt him. But if I dropped it from an aeroplane it would be accelerating faster and faster and when it hit someone on the head it would kill him."

This at once reveals the boy's (not silly, though as we see it confused) view of gravity.

It seems that children do not approach questions or experiments from a vacuum; they generally have pre-formed ideas, which may not be appropriate or coherent, but which may be held robustly. As countersuggestions or counterevidence may not change their ideas (which, though hopelessly confused, often survive through life) they can be discovered by mentally invasive questioning and experiment. Indeed this is a case where some clear inferences can be drawn from questions; for the children's questions may be most revealing for how they see, or think they see.

Edith Guesne describes some experiments with children on light and vision. She finds that many children aged around 15 years do not conceive of light as moving, and they have in our terms bizarre notions of shadows. Some children (aged 13–14 years) conceive of light as sent out from lamp bulbs; but not from other objects such as tables or books. Thus a French boy, who considered the eye as a receptor of light for a glowing stick, said for seeing a cardboard box:

"Here my eyes can go right up to the box ... it's my sight .... If it (the box) was fifteen kilometres away, I couldn't see it, because ... my sight isn't strong enough .... Because a box doesn't move, it hasn't any energy. A lamp for example moves, the light gets there .... The box, it's stuff that isn't alive."

This is remarkably like Plato's theory of vision in the *Timaeus*:

"The Gods cause the pure fire within us, which is akin to that of day, to flow through the eyes in a smooth and dense stream .... So whenever the stream of vision is surrounded by daylight, it flows out along the path of the eye's vision .... And this substance distributes the motions of every object it touches, or whereby it is touched, throughout all the body even unto the Soul, and brings about that sensation which we now term 'seeing'."

Typically, children think of objects as in a 'bath of light', with no link between objects and the eyes. This is essentially the mediaeval view. Thus, for Thomas Aquinas (1225–1274) seeing was 'grasping' the forms of things. This is clearly an analogy to touching, implying that vision works directly, without links. This is children's view; and it is the scholarly tradition behind J J Gibson's (1950) account of visual perception. This mediaeval account is very different from representational views, deriving from Descartes's projective geometry and expressed by Descartes as a theory of vision in his *Optics* (1637). Here he describes the retinal image (the Sixth Discourse) and the "multitude of small fibres of the optic nerve". Descartes was well aware of optical means for perfecting vision (the Seventh and Eighth Discourses) and the use of refracting lenses for telescopes which he thoroughly understood (the Ninth Discourse).
Now I wonder whether his familiarity with optical instruments (he describes how to make lenses in the Tenth Discourse) might be a key to how Descartes and other practical philosophers, including Newton, broke with the mediaeval tradition (which is also children's view) to accept the notion of links of light between objects and vision—thus making vision representative and only indirectly related to the world of objects—so separating perception and conception.

If this is so, as it seems to be historically, we might expect that children who have intimate experience of lenses and telescopes and microscopes might come to appreciate vision as representative sooner and more clearly than optical instrument-deprived children. This hypothesis should be testable. It might indeed be worth asking whether children who wear glasses think of vision differently (more like Descartes and Helmholtz) than those who don't. On this account, it would be surprising if Gibson wore glasses when he was a child!

The notion of recapitulation of past species through embryological development may be unfashionable, at least as applying in detail; but there is a case for something like it in how development of children's concepts partly mirrors developing explanations through the history of science. Perhaps the association is strong enough to suggest that hands-on experience of crafts and technology, suggesting scientific explanations (Gregory 1981), might throw light on what makes children individually develop understanding. How the 'seeing' of perception feeds into the 'seeing' of conception, and presumably vice versa, remains mysterious. But surely just how—through the generations and individually—we gain brains-on knowledge from hands-on experience, so that we 'see' both perceptually and conceptually, is a central question for education and for effective development and application of science. My guess is that a key requirement is questioning. Parents generally get bored with their children's questions, which perhaps is why children like interrogating infinitely patient computers; and given opportunities for finding answers (as in Exploratory Hands-On Science Centres) by asking direct questions of phenomena, and hidden wonders of the world.

Aristotle said that philosophy begins in wonder (Metaphysics, 982b12):

“For it is owing to their wonder that men both now begin and at first began to philosophize; they wondered originally at the obvious difficulties, then advanced little by little and stated difficulties about the greater matters, e.g. about the phenomena of the moon and those of the sun and of the stars, and about the genesis of the universe.”

Do young children raise philosophical questions? This has been asked, and in some degree answered, by an American teacher of philosophy at Amherst, Gareth Matthews, in Philosophy and the Young Child (1980). He starts with Tim (aged about 6 years) who, while licking a jar, asked: “Papa, how can we be sure that everything is not a dream?” His father said he didn't know. Tim answered: “Well, I don't think everything is a dream, 'cause in a dream people wouldn't go around asking if it was a dream.” But there is no way for a child or adult to check this assumption.

More empirical is the example of the boy John Edgar, who had often seen aeroplanes take off and disappear in the distance. He flew for the first time at the age of 4 years. After takeoff, when he was released from the seat belt, he turned to his father and said in a puzzled voice: “Things don't really get smaller up here.”

Matthews (1980, page 5) suggests that as Edgar sees objects on the ground as small in much the same way that aeroplanes shrink in the distance, so he may come to distinguish appearance from reality. Surely this suggests some interesting experiments. Is a single dramatic experience, like flying for the first time, sufficient for a drastic paradigm change in children? Do children need more, or less, 'torpedo' experiences to change their perceptions or conceptions than adults?
Ursula (3 years 4 months old) said, (Matthews 1980, page 17): “I have a pain in my tummy.” Mother, “You lie down and your pain will go away.” Ursula, “Where will it go?” All children ask questions like these. They arise by analogy with toys, food, and so on going somewhere else. But how do children recognize that some analogies lead to puzzles—and tease language for an answer? Indeed, children do philosophize.

Perhaps most people give up philosophy by the age of ten or so. In the dialogue the Gorgias Plato approves of this, effectively recommending the giving up of word-play to take up conceptual intercourse with the world:

“It is a fine thing to partake of philosophy just for the sake of education, and it is no disgrace for a lad to follow it: but when a man already advanced in years continues its pursuit, the affair, Socrates, becomes ridiculous; and for my part I have much the same feeling towards students of philosophy as towards those who lisp or play tricks.”

Plato has the last word.

Well, not quite the last word. Let’s look, even though ridiculously briefly, at how the New Physics of Galileo, Kepler, and Newton changed scientific perception and yet has hardly affected how most of us see the world we live in. This is suggestively discussed by I Bernard Cohen in The Birth of a New Physics (1985). Considering early (which are essentially children’s) notions of motion, especially the moving Earth, Cohen writes (page 3): “Odd as it may seem, most people's views about motion are part of a system of physics that was proposed more than 2000 years ago and was experimentally shown to be inadequate at least 1400 years ago.” Cohen goes on to say:

“In the inability to deal with questions of motion in relation to a moving Earth, the average person is in the same position as some of the greatest scientists of the past, which may be a source of considerable comfort. The major difference is, however, that for the scientist of the past the inability to resolve these questions was a sign of the times, whereas for us moderns such inability is, alas, a sign of ignorance.”

Clearly, much the same applies to children’s compared with adult notions. Most adults retain ancient views of motion and force and so on, shared by children, in spite of many centuries of scientific understanding which is presented (however ineffectively) in schools. Cohen makes the interesting point that although as adults most of us know in a sense that the Earth is moving—for, if asked, possibly most people will say it rotates around its axis and goes round the Sun yearly—yet very few appreciate the implications, and so do not see this or motion in general coherently in depth. An ancient objection to the Earth rotating was absence of a continuous wind (of around 1000 miles per hour at the equator) for, given the assumptions of the time, there seemed no reason for the air to move with the Earth. And a projectile shot up vertically should land West of its ascent. More generally, a ball or whatever thrown up vertically from a moving carriage should land behind the carriage, not on it, so clearly false predictions are generated. After millenia of thought and experiment, these matters are still not in the accepted intuition of nonscientists; and many scientists have a hard time ‘seeing’, for example, why gyroscopes precess at right angles to an applied force even though this follows directly from Newton’s familiar first law of motion.

As we grow up from childhood we seldom grow into a consistent way of seeing phenomena, or how things interact. Indeed, to ‘grow up’ suggests (like Plato’s account of learning in the Meno) that there is a natural development, something like plants growing; yet the fact is that Natural Science is highly unnatural for us. For, most often, we fail to escape from puzzles and confusions which, though charming in children, are literally blinding ignorance in adults, and sometimes incapacitating to the point of being highly dangerous, when how we see fails to match the way things are.

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