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## History and Philosophy of Science, Cognitive Science and Science Education *Issues at the Interface*

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### ABSTRACT

*We review some research relating philosophy of science and cognitive science with science education. Since the 1960s, science education research and curriculum development have been subtly or explicitly influenced by theories of learning. Piaget's influence led to a shift from behaviourism to constructivism. When, by the 1970s, Piagetian stage theory was found inadequate, philosophy of science, specifically the work of Popper, Kuhn, Lakatos and Toulmin, gained currency in science education. Ideas such as theory-laden observations, paradigm shift, and fruitfulness of theories, seemed applicable to concept learning as also to domain-independent issues related with conceptions of science and of learning. Developments in cognitive science too contributed research paradigms and methods, including expert-novice studies, problem-solving and linguistic analysis. We argue that an awareness of these trends might help avoid scienticism in science education, that the philosophy of perception and representation might guide research while work in the tradition of situated cognition might hold promise for a philosophy of praxis and action.*

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SCIENCE education of the sixties was dominated by curriculum reform movements. These movements, originating in the USA and UK, were inspired politically by the launching of Sputnik. The curricula were motivated by the need to communicate the nature of scientific inquiry, which it was assumed would also facilitate the learning of science. Despite initial enthusiasm, subsequent evaluations revealed that

the new curricula faced numerous problems in practice. Some of these problems were attributed to a mismatch between the intended and actual nature of science reflected in the curricula (Hodson, 1988, Duschl, 1988).

Early research in education was pervaded by behaviourist notions of learning. Learning was considered to be a passive accumulation of facts. It was with Jean Piaget's work (Piaget, 1954) that the presently popular constructivist paradigm in education replaced the behaviourist notions of learning. A prominent, constructivist, Ernst von Glasersfeld (Glasersfeld, 1991), however, traces the origins of this theory back to the Neapolitan philosopher, Giambattista Vico, who wrote a treatise *De antiquissima Italorum sapientia* in 1710. One of Vico's basic ideas was that epistemic agents can know nothing but the cognitive structures they themselves have put together, Vico emphasized that 'to know' means 'to know how to make' and humans can know only what they have constructed. According to Glasersfeld, constructivism is a form of pragmatism. It shares with pragmatism the attitude towards knowledge and truth, but differs from it in its predominant interest in how this knowledge, 'that enables us to cope', is arrived at.

From Piaget's perspective, cognition is an adaptive function. Glasersfeld believes that the technical sense of the term 'adaptive' comes from the theory of evolution, but has been misinterpreted by later researchers. He reads Piagetian construction of a scheme as consisting of three parts — recognition of a certain situation (e.g. for an infant, presence of a graspable item with a rounded shape at one end), association of a certain activity with that item (e.g. picking it up and shaking it) and expectation of a certain result (e.g. the noise it makes). According to him, Piaget's learning theory may be summarized to say that, learning takes place when a scheme, instead of producing an expected result, produces a perturbation. The perturbation, in turn, produces an accommodation that establishes a new equilibrium.

Piaget's constructivism led to a transition in the conception of learning as an active process that took into account the learner's interaction with the environment. His work also gave the child's world and views a special and important place. In science education, a new dimension of research, viz. the study of micro-genesis of specific concepts emerged. Although some of this research was carried out in the framework of Piagetian stage theory, more popular were studies of the understanding of specific concepts in science. These studies

continued to focus on the child's theory-building, while looking at micro-structures rather than the Piagetian stages (Driver and Easley, 1978). The methodology of clinical research, which involves questioning based on the learner's interaction with certain physical objects in specific tasks, came to be widely used. The subsequent years led to the accumulation enormous amount of empirical data on children's conception of the world.

By this time, curricula developed in the US and UK were facing stringent criticism from the philosophy of science quarters (Wellington, 1981; Hodson, 1988). Many of these teaching schemes had been developed to present science as a coherent system of ideas and to convey the spirit of scientific inquiry. However, in practice the curricula reflected a rather simplistic view of the scientific enterprise which was rooted in the empiricist belief that all knowledge is based on observation (Driver, 1993).

The justification for applying ideas from the philosophy of science to science education, could be found in the 'child-as-scientist' metaphor, which had been subtly present since Piaget. Since children could be considered novice scientists, researchers in science education thought that philosophy of science, which attempted to lay down the foundations for science and scientists, could similarly be used to interpret children's conceptions of science and provide guidelines for the same. As Confrey (1988) has pointed out, philosophy of science allowed researchers to critique the underlying 'inductive' conception of science which permeated science textbooks in the form of 'the scientific method', and also helped interpret the empirical observation that students enter instruction with a firmly held set of beliefs.

Among the philosophers of science, Kuhn, Popper, Lakatos and Toulmin have been the most influential in science education research. Science educators motivated by Popper emphasize the hypothetico-deductive method in science curricula. Kuhn's (1962) idea of a paradigm to refer to theoretical and methodological commitments shared by a community of scientists, led to the idea that children were like scientists in their rigid beliefs regarding concepts in science. Science educators argued that to alter student's conceptions required intellectual transformations similar to those accompanying a scientist's moving from one paradigm to another (Hodson, 1988; Carey, 1985).

Conceptual change in students was seen in the light of Toulmin's proposal to replace Kuhn's revolutionary view of science (Toulmin, 1970) with an evolutionary view. According to Toulmin, it is not the

intellectual doctrine adopted by an individual or a group at a certain point of time that concern questions of rationality, rather, it is the conditions on which, and the manner in which they are prepared to criticize and change those doctrines over time. Toulmin stressed that conceptual change is not the mere replacement of one theory by another. It is rather a variant of the theory which is selected. In order to understand the progress of science, it is important to identify what affects the selection of this variant. Following from Toulmin's work, science education researchers have attempted to study conceptual change in children particularly in the domain of science and also attempted to design methods to foster conceptual change (Nussbaum, 1983).

Lakatosian notion (Lakatos, 1970) of a 'hard core' in the context of research programmes in science has been invoked by science educators to re-emphasize the distinction between belief and knowledge (Cobern, 1993). Feyerabend's (1975) argument that science cannot be characterized by any single 'method' has also been acknowledged by various science educators.

These ideas however do not seem to have influenced the practice of science education research or curriculum development.

In the following paragraphs, we will briefly instantiate some themes from the philosophy of science that have found a place in science education and have led to various research studies. The themes fall under two broad categories: domain-specific (related to the conceptual content of science) and domain general (related to the conceptualization of science).

## **Domain-specific Issues**

### *Conceptual Structure*

The move from behaviourism to constructivism emphasized the importance of prior knowledge in learning. The child-as-scientist metaphor, as also the work of Ausubel (1968), led to the belief that just as scientists' conceptions are affected by pre-existing conceptions, students' learning is affected by their pre-conceptions. It was hence thought necessary to study prevailing conceptions among students.

Various topics such as force, curvilinear motion, torque, simple circuits, light, heat, life, mole concept, atomism, evolution, etc. have been studied. It has been seen that notions not conforming to scientific understanding of concepts prevail despite formal

instruction. They are referred to as alternative conceptions or alternative frameworks by education researchers. Pfundt and Duit (1993) report more than 4000 studies in their bibliographic collection spanning about two decades of research.

Some of the research on conceptual structure and conceptual change has used a cognitive science methodology of expert-novice comparisons (Kaufman et al., 1996). In these studies, expertise is first determined in terms of performance followed by an analysis of cognitive processes that mediate performance. A model consisting of knowledge representation, strategies and mechanisms of learning is proposed, to account for the observed differences in performance. Learning sequences are then designed to enable attainment of superior performance. Several tools have been used for studies of conceptual structure, the most prominent being the concept map (Novak, 1990) described in the next section.

Another important trend in the studies of conceptual structure is based on the assumption that students' alternative frameworks mirror the historical development of a concept. Such comparative studies are fewer than those of student's naive conceptions and are confined to developmental studies in a few subject areas, like evolution and mechanics. Several studies claim that students' conception of evolution are primarily Lamarckian (Bishop and Anderson, 1990; Aleixandre, 1994; Settlage, 1994). Many of these researchers have suggested and evaluated teaching strategies to affect conceptual change. Aleixandre, 1994 has indicated that strategies that draw from historical materials increase students' understanding of evolution.

Saltiel and Viennot (1985) observe that students' reasoning in mechanics resembled those of Philoponus (6th century). Halloun and Hestenes (1985) remark that Buridan's (14th century) notion of impetus is a clear articulation of student's vague ideas. In an article addressing the relevance of cross-cultural studies, Thijs and van den Berg (1995) have included a concise overview of studies relating to concepts in physics and their historical parallels.

### *Conceptual Change*

Research was carried out not only to study conceptual change but also to identify constraints to learning. Novak and Gowin (1984) have described the method of having concept maps constructed by students and have also demonstrated an increased effectiveness of their use in learning of concepts. As reported by Novak (1990),

concept maps owe their origin to Ausubel's dictum that the most important factor in students' learning is their prior knowledge. Ausubel is also believed to be the first to represent students' conceptual knowledge in the form of schematic maps in order to observe changes and map their progress. Concept mapping in conjunction with laboratory instruction has also been studied as a learning tool. Stensvold and Wilson (1990) found that they assist students with a low vocabulary but hinder those with a good vocabulary.

Another methodological tool developed to study conceptual organization in students was the computer program called Sem Net (Fisher, 1990). Sem Net allows formulation of multi-dimensional maps and facilitates integration of many ideas into a single sophisticated structure.

Influenced by Toulmin's idea of conceptual change, Posner et al. (1982) propose a theory of conceptual change for science education. They base their analysis on a study involving students' learning of special relativity via traditional instruction. Posner et al. suggest that a change in existing conception requires students to be faced with anomalies that create a dissatisfaction in the existing conception and thereby make space for a new conception. Students also need to find the new conception intelligible, plausible and fruitful. Hewson, (cited in Confrey, 1989), elaborates that when competing conceptions are presented children raise or lower the status of one conception relative to another. Posner and Strike later modified their model to reduce its 'excessive rationality' by allowing for contextual influences (Cobern, 1993).

Dykstra et al. (1992) propose a taxonomy of conceptual change, based on Posner's general strategy. They describe three types of conceptual change, viz. differentiation, class extension and re-conceptualization. Differentiation refers to the emergence of new conceptions from existing conceptions, as for example velocity and acceleration from ideas of motion in kinematics instruction. Class extension refers to those cases where the existing concepts considered different are subsuming concepts. For example, rest and constant velocity are equivalent in the Newtonian point of view.

Re-conceptualization refers to those cases where a significant change in the nature of and relationship between concepts occurs. For instance, changing from force implying motion to force implying acceleration.

Chi et al. (1994) have proposed an alternative theory of conceptual change based on ontological categories. They base their

theory on the supposition that the entities of the world can be classified into three primary ontological categories viz. 'matter', 'processes' and 'mental states'. 'Processes' are further categorized into 'events', 'procedures' and 'a causal processes'; matter into 'natural kinds' and 'artifacts'. These are distinct in that the attributes of one category cannot be applied to those of another. Chi et al, suggest that misconceptions arise when a concept is assigned an incorrect ontological status. For instance, heat, force, light, etc. are assigned the status of 'matter'. According to them, conceptual change occurs when a concept is reassigned to an ontologically distinct category.

Many researchers in this tradition have attempted various methods of facilitating conceptual change. Major among these are the conceptual-conflict method and the anchor-bridges method. In conceptual-conflict, the student is posed with a counter-intuitive situations which impels a need to re-think the previously held conception (Stavy and Berkovitz, 1980; Nussbaum and Novick, 1982). The anchor-bridges model on the other hand starts with a situation where most children intuitively reason correctly. It then proceeds across several conceptual bridges to a target situation where previously most students have exhibited misconceptions (Minstrell, 1982; Clement et al., 1989; This and Bosch, 1995). For example, to teach forces on bodies at rest, a series of experiments have been suggested (This and Bosch, 1995). In the first series students have to apply either pulling or pushing forces on a cart that is forced to remain at rest by hand or by a hanging mass. The next two series of experiments have a bridging character. Students start with the question of whether the rest-rule applies also when the cart is stopped by a wall and a block is kept at rest by friction. In the bridging series the existence of a balancing force is made plausible by making its effect visible. The bending of a flexible ruler and of the hairs of a brush aim at triggering the students' discovery of the normal force and the force of friction respectively.

### *Cross-cultural Studies*

Cognitive science being a multi-disciplinary field, many important studies have drawn upon from sociology and anthropology. These studies, influenced also by trends in the cultural studies of science, have helped in the evolution of 'personal constructivism' into 'contextual constructivism' (Cobern, 1993).

The obvious dichotomy between westernized science education and the cultural beliefs that children hold, has motivated many

studies (Sayers, 1992). George and Glasgow investigated various science-related cultural beliefs in two Caribbean nations, Jamaica, Trinidad and Tobago, in relation to the science syllabi followed by school children there. They described aspects of 'street' science in terms of six themes: child rearing, nutrition, pregnancy and birth, temperature changes, changes in the physical environment and household practices and compared these with conventional school science topics such as diet, homeostasis, lightning and light, earthquakes, etc. They report that the two bodies of knowledge offer contradictory explanations and traditional beliefs play a major role in causing malnutrition in children in the region. (George and Glasgow, 1989) Various other studies (Sayers, 1992) have suggested use of traditional and local technology to teach science. George (George and Glasgow, 1988) uses the example of the steelband, a primitive hammering instrument that over generations developed into a sophisticated musical instrument. She discusses the possibility of including native technology to foster teaching of science and technology.

In biology, it has been seen that students hold their informal ideas on animistic conceptions of life, death as temporary and personified, and many others despite formal instruction. Brumby found that university students were unable to extend the school-learned concept of life to unfamiliar contexts (Brumby, 1982). Comparative studies done in the Indian context (Chunawala et al., 1996; Natarajan et al., 1996) of tribal and urban children's conceptions, show that their notions of life, including their likes and dislikes for plants or animals are shaped by the cultural and social significance attached to these.

Thijs and van den Berg (1995) use data from studies in the Netherlands, Indonesia and various African countries on alternative conceptions in physics and show that most of the documented conceptions bear a striking resemblance across cultures. They conclude that the culture-influenced conceptions generally pertain to Biology, for instance, conceptions of health, illness, fertility, growth etc, while those in physics are universal. The scientific world view represents a foreign sub-culture in all countries and cultures and the spiritual and religious beliefs do not interfere with the cognitive systems. They claim that it is in the student-teacher interactions (classrooms that allow questioning as against those that do not) that culture really interferes. Therefore it is not necessary to confirm alternative conceptions in every culture but necessary to work out the remediation strategies.



*Language*

Some work has been devoted to exploring the relationships between the use of scientific terms like force, energy, heat in daily life and the precise definition they have in their discipline. Mibiol (cited in Sayers, 1992), interviewed five students in three schools of Nigeria to test their understanding of certain science concepts. The investigator maintains that the basic source for misconceptions "was either due to the absence in their first language of a number of words ... or the absence of certain concepts". The word used by students for respiration actually meant 'breathe' and oxygen was referred to as 'air'. Veiga et al. (cited in Sayers, 1992), analyzed the language used by teachers and found that teachers use naturalistic language inter-mixed with scientific language, which can lead to misconceptions, for example, when saying "energy comes from the sun". They suggest that if teachers became more aware of the descriptive language they used then it might help avoid some misconceptions.

Other studies have aimed at understanding the role of student's use of infernal analogies to understand complex scientific concepts. Gick and Holyoak (1983) conducted a series of studies using a problem involving radiation. An analogous story problem was presented before the problem. Relatively low percentage (30 per cent) of subjects produced the correct solution. Only 10 per cent generated the correct response in the absence of the analog while 75 per cent gave the correct response on being given an explicit hint that the stories were related.

Bassok and Holyoak (cited in Kaufman et al., 1996), investigated the inter-domain transfer of procedures between algebra word problems and physics problems. In particular, they studied transfer of knowledge between a set of arithmetic-progressions problems in algebra and a set of constant-acceleration problems in physics. Subjects learned to solve problems in one of the two domains and then were tested on the other domain. The goal was to determine if they could transfer the solution method learned in one domain to another domain.

Algebra-trained subjects immediately retrieved the relevant equation and applied the solution method to the physics problems while physics-trained subjects almost never exhibited any spontaneous transfer to the algebra problems. Researchers claim that students who knew the conditions under which mathematical procedures apply, screened out content-specific details of the algebra word problems while students who were trained to solve physics

problems, having learned the content-specific applicability conditions, failed to solve algebra problems.

### **Domain-general Issues**

So far we have highlighted some trends in research pertaining to specific subject areas. We now provide a brief overview of the complementary trend which deals with the so called domain independent studies. These include epistemological studies, studies on reasoning, and scientific thinking and coordination of theory and evidence among others.

#### *Nature of Science*

Various arguments have been drawn out for the necessity of understanding the nature of science (Driver et al., 1996). Major ones include that it helps people make sense of the science and manage the technological objects they encounter everyday. It helps people understand socio-scientific issues and participate in the decision-making process. It also develops an awareness of the nature of science, and norms of the scientific community. It fosters appreciation of science as a major element of contemporary culture and also supports successful learning of science content.

Under this tradition, various studies have been carried out to study students' understanding of the scientific world and their conceptions of the nature of theories, hypothesis, experiments, and explanations. Carey et al. (1989) devised a teaching lesson designed to facilitate children's move from an inductivist epistemology (where scientific knowledge is seen as emerging from observation) to a hypothetico-deductive epistemology (where experimentation and observation are seen as purposeful theory-driven activities). Solomon et al. (1994) in a similar study designed a teaching intervention based on episodes from the history of science.

#### *Scientific Reasoning*

Many researchers have studied children and adults ways of reasoning in science and everyday contexts. One of the most well-known studies on scientific thinking in the recent past has been made by Deanna Kuhn and her colleagues (Kuhn, 1989). Kuhn et al. use several tasks to study subjects' ability to coordinate theory and evidence. Subjects, for example, were asked to generate hypothesis about whether eating one type of food than another was more likely to cause colds. Their

emphasis was on seeing how subjects reacted to subsequent information that either disconfirmed or confirmed their initial hypothesis. The researchers conclude that at all ages, especially, among younger subjects (below age 12) there is a fairly pronounced inability to coordinate theories with instances of the theory. This inability, they claim, is due to a related inability to think *about* theories rather than *with* them.

Samarapungavan (cited in Driver et al., 1996), challenges Kuhn's claim that general skills of coordinating theory and evidence develop with age and are absent in early childhood. She investigated the ability of children aged 6-11 years in theory choice tasks. Children were presented with simple data about a phenomenon and given two possible theories which might explain the data. She reports that 85-90 per cent of the children were able to make and explain theory choices.

Schauble et al. (1996) use theoretically rich tasks for the study of scientific reasoning. Their task involved systems with fluids and immersed objects. Participants attempt to discover the causal relations between variables and outcomes. In the system, various parameters like the size, weight and cross-sectional shape of the boat, and depth of the canal, were variable. Schauble concludes that the strategies that subjects use is affected by not only by their knowledge of the skills and processes but also their conceptual knowledge base. Both these bootstrap each other.

In a recent book *Theory and Evidence* (Koslowski, 1996), Barbara Koslowski legitimately argues that the prevailing view of scientific enquiry in the psychological literature carries the legacy of logical positivism. Studies of scientific reasoning are characterized by an emphasis on covariation and a corresponding neglect of theory or mechanism. She argues through a series of empirical studies that when subjects assess information, their assessments are tempered by prior knowledge about mechanism and information about alternative accounts. Most studies of scientific reasoning ignore this possibility and hence label subjects' reasoning as being flawed. Koslowski argues that the few age differences which are observed can be easily attributed to differential background information. She suggests based on her studies that students should be explicitly taught to attend to knowledge about various related areas in order to decide which alternatives are plausible and ought to be controlled in any experiment. They must also be taught explicitly not to reject a hypothesis immediately in the face of anomalous evidence. Rather

students must learn to look for patterns in anomaly so as to be able to refine their working hypothesis.

### **Comments and Criticisms**

In the preceding sections, we have attempted to highlight some of the main issues that interface science education, history and philosophy of science and cognitive science. It has been seen that since the time researchers began utilizing developments in the philosophy of science as a foundation for studies in science education, there is a heightened awareness among the community of science educators of the view of science that underlies research studies, and that gets communicated through various curricula. It also seems that an exposure of science educators to contemporary philosophy of science and history of science would broaden their perspective on the issues that underlie this tradition of thought. This would perhaps aid a shift away from the scientific legacy that marks the present day science education.

#### *Pupil-as-Scientist Metaphor*

As we have pointed out earlier, research interlinking philosophy of science with science education seems to be a fallout of Piagetian constructivism and the pupil-as-scientist metaphor. This metaphor not only motivated studies of students' alternative conceptions but also generated studies that revolve around the debate of whether they can indeed be called novice scientists or not.

Carey (1985), Driver and Easley (1978), McCloskey and Kargon (cited in Brewer and Samarapungavan, Vol. 3) take the stance that children construct theories which are very similar to scientists' theories while DiSessa (1988), Solomon (1983) and others have argued that children's theories are very different from scientific theories. Those who argue that children's theories are not like scientists', claim that unlike scientists, children's theories are inconsistent, context-bound, lack explanatory power, and are concrete. Brewer and Samarapungavan (Vol. 3) point out the difference between science of the individual and institutionalized science and argue that differences in reasoning of children and scientists as documented by researchers are due to their failure to acknowledge this difference. They point out that pre-Newtonian theories of tides, terrestrial motion and celestial motion appear to be context-bound compared to Newton's theories. Inconsistencies

in individual scientist's theories are in fact recognized because of the presence of written texts and are overcome over long periods of time. With examples of interview protocols on observational astronomy, they also show that children use their own alternative models as explanatory frameworks to answer novel questions.

### *Lakatosian Underpinnings*

What is interesting to note in Brewer's work, is the beginnings of the long overdue move towards a Lakatosian framework. In philosophy of science, an important shift in moving from the Popperian framework to the Lakatosian framework was a corresponding shift to research programmes from individual theories as the measure of progress in science. This complemented a recognition of the fact that a normative dimension which is to guide the progress of science cannot arise from outside the practice of science, it has to reflect the actual enterprise of science. In a similar vein, one is impelled to ask how a normative dimension to rationality in children might be dictated from outside the child's framework or worldview.

No comparison of scientists and children can afford to ignore the fact that the scientist works within a research programme, and his/her functioning is influenced by the interplay of various interactions within the community. If one has to understand the functioning of the child, then one needs to identify what constitutes and characterizes the research programme for a child. One inherent difficulty in such an endeavour would be the fact that the scientific life-world constitutes a single sub-culture while a child's life-world constitutes several such sub-cultures (for instance, home, school, peer group and so on). Clarity on how far these sub-cultures are independent of each other, how they affect each other and interact in the child's worldview, might have implications for future work.

### *Pupils: Not Scientists*

A crucial point that is often ignored in science education studies of children's theories is the fact that the culture of science is an alien culture for most children. Children in fact need to be groomed to appreciate science or participate in it. Attempting to draw out the similarities or differences between children's and scientists' ways of reasoning seems to be analogous to comparing the wood of a table with the trunk of a fully grown tree. A tree trunk has taken its form over a long-time. It has grown with the efforts of people, watered,

nurtured with manure, and protected against bad weather. A table has been carved and given a shape as desired by the carpenter. A tree survives despite one of its branches being diseased. Similarly a scientist has been trained in the tradition of science, and is living in a community working towards a shared goal, held by a common core; where despite anomalies in individual theories, the programme is sustained by other members of the community. Children perhaps do not share similar goals as those of scientists and therefore, debating on whether their views are like or unlike scientists is too constrained a line of thought and rather superfluous. A child is yet being 'taught' the ways of science. It is important to recognize that the world of science which is the life-world of the scientist is not the life-world of the child—a tree is living while a table is not.<sup>1</sup> By arguing so, we do not however intend to say that a child's life is passive and moulded completely by others. Rather, a child's world is wider than a scientist's and encompasses many worldviews besides science. Therefore, the situation in which a developmental psychologist poses a task or a problem from science to the child and interprets her response against a scientist's theory remains merely an artifact used by the researcher but does not throw any light on scientific rationality in children. The child's rationale would borrow its premises from theoretical or empirical perspectives from many worlds, not only science.

### *Scientific Reasoning*

The other important point to note, is the tendency to be prescriptive about what constitutes scientific reasoning, which pervades studies relating to domain-general issues that we described earlier. As we have already mentioned, Koslowski points out, that these studies are dominated by the empiricist view of science which ignores the role of theory or mechanism. There seems to be a normative undertone in most research in this tradition with regard to what scientific reasoning is. However, both in developmental psychology research and in philosophy of science, there has been as yet no clear consensus as to what marks scientific reasoning. Let us take for instance, the debate on the pupil-as-scientist metaphor. The line

<sup>1</sup>Extending this analogy too far may only lead us astray from the main point. For instance, unlike a table, a child grows and learns, and is creative. The analogy simply intends to stress the significance of recognizing science as a tradition of thought alien to most children and one that needs to be taught. It does not seem appropriate therefore to compare children with scientists already trained in this tradition.

of argument that individual scientists may also be inconsistent, and context-bound like children and laymen, or that children also construct theories that are coherent within their framework, and so on, does not seem to clarify, however, as to what it is that is *scientific* in any particular instance of reasoning. It seems that domain-general studies of scientific reasoning or thinking which rely on philosophy of science only seem to provide a mapping of students' ideas against a background of philosophical perspectives, but are yet to provide any leads for the communication of science.

### **Suggestions**

#### *Philosophy for Science Education*

The question that continues to remain then is whether and how can philosophy contribute to communicating science better. What might indeed be fruitful in this endeavour seems to be the study of science as a form of representation. The important point, often undermined, that emerges from many studies of students' conceptions is the fact that students are context-bound. The abstraction or idealization of these complex contexts, often involved in theorizing in science, is what is alien to them. Ramadas (1982) observed that students tend to draw realistic sketches of situations when asked to draw schematic representations. For instance, when asked to draw how the sky or a boy sitting on the bank appear to a swimmer under water in a lake, students draw the surface of water as a blur or with ripples and state that very little would be seen through it because of the ripples or because of muddiness. It is, therefore, crucial to clarify this connection that links real world situations and their scientific representations. Not merely interpretation (such as that of a graph or a schematic diagram) but the process of representation (such as, steps involved in the generation of a schematic diagram from a given real-world situation) involved in science requires to be clarified. De-linking situations from their scientific representations not only makes conceptual learning difficult but also creates epistemological conflicts as to the purpose; relevance and significance of learning science. It is here that the philosophy of perception and representation might have important leads for science education.

#### *Science Education for Philosophy*

Coming to the question of how science education might contribute to philosophy, one needs to look at an important area in educational

research, viz. situated cognition. Researchers in this paradigm challenge the traditional western view that cognition can be examined independent of culture. Most studies in this tradition have been carried out in the area of mathematics education and problem-solving competencies. Magalhaes and Schleiman (Light and Butterworth, 1992) studied proportional reasoning among cooks in Brazil. Sixty cooks between between 16 and 40 years with almost no schooling were tested on proportionality problems in a sales transaction context, cooking context and the context of a pharmaceutical mixture of ingredients. Subjects were split into three groups. The first group was given problem in the order, recipe, price; recipe and then medicine problem. The second was given problems in the order price, recipe, medicine, recipe and the third was given the problems in the order medicine, price, medicine, recipe. It was found that there was a striking increase in correct response in both Inedicine and recipe problem when they followed the price problem. The increase however was not so high for medicine problems when they were presented before the recipe problems but after the price problems. It is clear from this example that familiar context, cooking in this case, aids transfer of learnt procedures to an unfamiliar context. This work also exemplifies that concepts are, in fact, deeply rooted in actual situations and practice. This is likely to be the case not only in mathematics but also, and more so in the case of science. Most work in the area of situated cognition is however, so far in mathematics and there seems to be an urgent need to extend this to the domain of science. The standard practice of designing novel activities and situations to communicate various concepts in science or mathematics needs to be supplemented with a thorough exploitation of possibilities that pre-exist in specific cultural contexts. Situated cognition seems to hold promise not only for science education but also for the development of a philosophy of praxis and action.

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