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Epistemological basis of science and its implications toPedagogy of science

Dr. Manjula P RaoManasa GangotriMysuru, Karnataka
Professor of EducationDepartment of EducationRegional Institute of Education (NCERT

Abstract:- The epistemological views and beliefs regarding the perceptual world and construction of knowledge related to it may be traced back to the schools of objectivism and subjectivism. The objective view of knowledge had influenced the methods of psychology and education until recent years, which was criticized for its passivity and behaviouristic approach to knowledge generation. The emergence of subjectivists view against the objectivism had resulted in the new outlook to understanding the nature of science and its processes, which led to a paradigm shift in understanding of science and its processes. The shift in perspectives of science and its methods has also influenced the perspectives of science education – its aims, methods, processes involved in knowledge construction. This paper has analyzed the shift in the perspectives of learning science with a focus on subjectivists' views on knowledge construction. The paper discusses about its implications to understanding of learning process in the context of science learning. Syntheses of various approaches that facilitate cognitive processes, conceptual changes in the process of construction of knowledge in science are discussed.

Key words : *Epistemology, Constructivism, objectivism, Subjectivism, learning process in science*

I. INTRODUCTION

Science teaching in our country has continued to remain mechanical and ritualistic in its aims, approaches, methods and assessment. It has remained unresponsive despite the curriculum and textbook reforms that took place from time to time based on the recommendations of educational policies, committees, National curriculum frameworks. Call for reform in science education has increasingly focused on the pedagogical approaches used in the science classroom to motivate learners, to develop cognitive processes and application skills in learners. Many studies have shown that science teachers do not know the nature of scientific knowledge, though they may have content mastery in the respective branches of science discipline. The most prevalent idea amongst science teachers is that, knowledge in science discipline is arrived at by the application of scientific method which is objective in itself, to know and understand the physical world in which we live in. This view of science and science teaching has been increasingly challenged by science educators like Hodson (1985), Mathews (1989), and Abimbola (1983). It is felt that many problems in science education stem from the improper ways of handling the subject and lack of understanding the structure of knowledge in science. This may be attributed to the teacher education curriculum in our country which has failed to take into cognizance of the necessity of incorporating philosophical and historical dimensions of science that lead to understanding the structure of knowledge in science. Thus, the budding teachers who step into the world of school tend to be short visioned in their understanding of the discipline and in their class room transactions. The typical views of science and science instruction that are short sighted have been under continuous criticisms in several forums which call for a change in the perspectives on science and science instruction. An approach to school science which incorporates historical and philosophical dimensions increases not only understanding of science in its right perspective in teachers, but also helps teachers to view the aims of science teaching, the learning processes and the cognizing mind of the learners differently. Shifting from positivist view of looking at science, where the role of cognizing mind is denied, to the view of science-in-the making provides newer insights into understanding science –its structure, its process, and its evolution in explaining the world around, and to view science learning as a process of knowledge construction. This paper discusses about such epistemological shifts and their overtones to science teaching that offer many pedagogical opportunities which are of specific interest in knowing the world around.

II. EPISTEMOLOGICAL BASIS OF SCIENTIFIC KNOWLEDGE

The Indian and western philosophical systems have always been concerned with many questions related to nature of the world, its reality, nature of knowledge , its validity, truth and belief, ways of knowing and so on. The epistemological questions related to knowledge, its sources, and validity of the sources of knowing has been of great importance in understanding various forms of knowledge which have later been classified into different disciplines. The philosophy of science addresses some of the fundamental issues in science, like, how is

scientific knowledge created?; How does scientific knowledge gain acceptance within an intellectual community (Kuhn, 1970); What sociological factors influence the nature and growth of scientific knowledge ; and what is the purpose of creating new knowledge? Although there are many different epistemological views regarding these questions, in general, epistemological beliefs are seen as ranging on a continuum from objectivism to subjectivism Objectivism which is also referred to as empiricism and logical positivism advocates the belief that knowledge of the world exists outside the knower which is relatively fixed and it is for the individuals to know it. Objectivism also believes that the knowledge is independent of the knower. It is asserted that man comes to know the objects around through his sense perceptions which create a mirror image of the objects in the mind. It is believed that the trueness of knowledge of things around happens when it corresponds exactly with the objects in the external world. Those who subscribed to this objectivists' view point believed that the concepts in the mind are formed due to the corresponding sense impressions made by the objects around on the mind. Influenced by this thought, traditional philosophies of science believed that science is the search for truth based on observation and other empirical means. The more that one knows about a concept, the closer the representation of knowledge in that person's mind is to the reality of the world which is referred to as the "reality constructs the person" paradigm (Evans, 2000). According to this paradigm, knowledge represents the real world that is existing, independent of the knower; and this knowledge should be considered true only if it corresponds to the independent world. Objectivism subsumes all those theories of knowledge that hold that a proposition is true only when it can be tested and proved empiricallyIn contrast to the traditional views of science that which claimed that science is search for truth, and that as scientific theories progress, we come closer to knowing that truth, the recent philosophies believe that science consists of solving problems and that scientific theories are tools to be used in solving problems and generating new research. The traditional views of science that it is accumulation of knowledge was also challenged by Kuhn (1970) who said that science progresses through changes in knowledge. He suggested that instead we make paradigmatic shifts where we rebuild our 'true' coordinated schemes based on our new view of the world. New paradigms replace old ones which may be seen in the history of science, for example in the works of Galileo, Newton, and Einstein. Kuhn states that 'Scientists never learn concepts, laws and theories in the abstract and by themselves. Instead, these intellectual tools are from the start encountered in a historically and pedagogically prior unit that displays them with and through their application' (p.46). Similar changes in knowledge occur in the individual when learning new concepts. We tend to reorganize our existing ideas on reflection or inquiry or in light of new experience which is more meaningful and justifiable

Though there have been divergent opinions about scientific knowledge and its structure, some philosophers of science, especially, Kuhn, Lakatos and Toulmin converge on certain points to arrive at a common platform of understanding of science which has an implication to science education. The critical analysis and arguments have led to the emergence of new philosophy of science which suggests that scientific knowledge cannot suggest an absolute truth. Instead the errors and the temporary status of science must become the object of reflection. It is argued that the scientific discoveries have context and structure and there cannot be one singular method of producing scientific knowledge and the role of scientific theories is to interpret and explain the world tentatively. In the place of traditional view where science has been viewed as objective and impersonal knowledge, the new philosophy of science viewed science as closely related to society and technology. Thus in the history of epistemology, one can see the trend of moving from static, and positivists views of knowledge towards subjectivists view of knowledge which is based on the logic of interpretation. According to subjectivists, knowledge and truth are created, not discovered and world is known through people's interpretation of it. Truth is arrived at not by seeking correspondence as objectivists would say, but by seeking consensus. Truth according to subjectivists is relative rather than absolute depending upon time, place, interest and purpose.

The new philosophy of science also draws attention to the social construction of science, scientific knowledge and the associated technological development (STS perspectives, Matthews 1994) and the importance of the inclusion of the history of science in science teaching. These views have great implications for science teaching, where there is a need to make a paradigm shift from objectivists approach to subjectivist approach to understanding of learner and learning process. In practical terms we need to improve conditions which will enable teachers to analyze their teaching after a guided reflection on a previously selected theme of the curriculum.

III. SHIFT IN PERSPECTIVES OF LEARNING SCIENCE

It is observed by many science educators that, most science teaching is based on an objectivist view of knowing and learning. The scientific method which is used as a method of inquiry into science investigations is considered as the only way of testing propositions to ascertain absolute truths. Traditional approaches to science teaching and learning have focused on students memorizing facts about science and using algorithms to solve prescribed problems. The teachers and the textbooks have assumed the role of the principle sources of

knowledge, and paper and pencil tests have exerted a major driving force on the curriculum. Evidence for these claims in India and in other parts of the world, is the number of reports and studies which have identified serious shortcoming in elementary and secondary education. The positivistic approach to teaching and learning of science emphasized the obtaining of knowledge through objective means aimed at verification of known facts and principles. Success in learning was measured by the extent to which obtained results reflected existing theory. A key approach to teaching and learning was guided discovery with proof and conclusions as the most significant learning outcomes of science teaching. The teacher's role in this was primarily to provide information and procedures for investigating scientific facts. The role of education is to help students learn about the real world. The goal of curriculum designers and teachers is to interpret events for them. Learners are told about the world and are expected to replicate its content and structure in their thinking. This objectivist model has resulted in somewhat of a stereotyped portrayal of teaching and learning which is a widely criticized and often evoked as the target of educational reform.

Despite the existence of a variety of perspectives on the nature of science which shape the way people conceptualize and transmit it to others, current assumptions of science and science teaching appear to be shifting from traditional logical positivism to encompass new discourses in constructivism, inquiry and reflective practice (Lederman 1992). It is acknowledged widely in most of the developed and the developing countries that science teaching has undergone a significant paradigmatic shift from a positivistic approach based on the notion of the existence of external truths and the detached nature of knowledge, to a post positivistic stance based on a new conviction that knowledge does not exist outside the consciousness of people. Constructivism has been said to be post-epistemological, where it is considered as a way of thinking about knowing, a referent for building models of teaching, learning and curriculum. The philosophers such as John Locke (early18^{th} century) taught that no man's knowledge can go beyond his experience. Immanuel Kant (late 18^{th} to early 19^{th} centuries) explained that the logical analysis of actions and objects lead to the growth of knowledge and the view that one's individual experiences generate new knowledge. John Dewey who was a proponent of constructivism emphasized that knowledge and ideas emerged only from a situation in which learners had to draw them out of experiences that had meaning and importance to them (Democracy and Education, 1916) and these situations had to occur in a social context, such as a classroom, where students joined in manipulating materials and created a community of learners who built their knowledge together. . Although the main philosophy of constructivism is generally credited to John Dewey and Jean Piaget , the other contributors are Bruner, Ausubel and Vygotsky (social constructivism) who had multiple positions on construction of knowledge. Despite some of the differences, all constructivist positions share some common beliefs about ways of knowing which are significantly different from behaviourist concepts regarding knowledge, knowers and learning. According to behaviouristic school, learning is conceived as a process of changing or conditioning observable behavior as result of selective reinforcement of an individual's response to events (stimuli) that occur in the environment. Behaviorism centers on students' efforts to accumulate knowledge of the natural world and on teachers' efforts to transmit it. It therefore relies on instructional approach which is largely passive, teacher-directed and controlled. The term behaviourism is used synonymously with objectivism because of its dependence on objectivist epistemology. In constructivist setting, knowledge is not objective; science is viewed as systems with models that describe how the world might be rather than how it is. The models derive their validity not from their accuracy in describing the real world, but from the accuracy of any predictions which might be based on them (Postlewaite, 1993). Science constructivists believe that concept understanding should precede the factual learning. Student thinking and understanding is highly valued as students are frequently asked to 'classify'. 'Predict', 'analyze', 'explain', and 'create'. Constructivism as an approach to learning permits students to form their own concepts and models of those things they observe, in the natural world. Children do this by discovering relationships and construct on their own as they manipulate and observe phenomena. The post positivistic approach assumes that children build their own understanding of the world and interpret it in various ways which reflect their specific circumstances and local environmental influences. Von Glasersfeld (1995) who is a Radical constructivist argues that 'From the constructivist perspective, learning is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction'. Fosnot (1996) adds that 'Rather than behaviours or skills as the goal of instruction, concept development and deep understanding are the foci'. But the challenge for educators, is to be able to build a hypothetical model of the conceptual worlds of students, since these worlds could be very different from what is intended by the educator.

IV. PEDAGOGICAL IMPLICATIONS

The role of the teacher in this is that of training young people in efficient ways of constructing and understanding the multiple social constructions of meaning and knowledge. This belief has become the justification for current science teaching methods which emphasize the importance of understanding young

peoples' naïve ideas of scientific concepts before teaching a new topic, the role of discussion in science teaching, and the centrality of investigative science which builds upon pupils' own hypotheses as a basis for seeking and developing an understanding of new ideas. Process rather than product is the key to teaching and learning of science and this has become the basis of the constructivism discourse in science teaching and learning. Constructivism provides some clear pointers towards teaching strategies that might assist learners in conceptual reconstruction such as: identifying students' views and ideas; creating opportunities for students to explore their ideas and to test their robustness in explaining phenomena, accounting for events and making prediction; providing stimuli for students to develop, modify and where necessary, change their ideas and views; and, supporting their attempts to re-think and reconstruct their ideas and views. There is a need to emphasize generative learning, questioning and hands-on inquiry strategies to promote children's conceptual knowledge by building on prior understanding, active engagement with the subject content, and applications to real world situations is necessary in science lessons. The other pedagogic approaches like discovery, experimentation, and open-ended problems need to be successfully applied in science. Use of students' ideas about science to guide lessons, providing experiences to test and challenge those ideas help students arrive at more sophisticated understanding. The role of the teacher is to organize information around conceptual clusters of problems, questions and discrepant situations in order to engage the student's interest and assist the students in developing new insights and connecting them with their previous learning. Ideas may be presented holistically as broad concepts and then broken down into parts. Some of the practices derived from cognitive psychology that can help students understand, recall and apply essential information, concepts and skills are advanced organizers (David Ausubel) and Concept mapping (Novak and Osborne). They are used to make lessons relevant, activate students' prior knowledge, help elaborate and organize the concepts in a hierarchical manner, thereby showing network of relationships, and encourage questioning and encourage accommodation of new knowledge. Inquiry on the other hand 'implies a constructionist approach to the teaching of science' which is open ended and ongoing, employing procedures used by scientists, based on self generated questions and predictions and providing explanations that are compatible with shared experience of the physical world. John Dewey has defined inquiry as "the active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusion to which it tends (Dewey 1936:47). Inquiry also helps learners to gather enough information to generate theories that will make new experiences less strange and more meaningful to them. The social constructivist theory proposes group learning where in the learners construct knowledge through interaction, negotiating views, analyzing issues and conceptualize meanings. If learning is seen as a process of constructing meaningful representations, of making sense of one's experiential world, it is possible for alternative conceptions in understanding the concepts to take place. But these errors should be seen in a positive light and as a means of gaining insight into how students are organizing their experiential world. Students come to classes with a diverse range of everyday or alternative ideas. These alternative ideas are influenced by direct everyday experiences, direct observations and perceptions, peer culture, language, teachers' explanations materials and media. They are held by students without them being aware that they are the ideas that they use to explain how their world works. There are many students who go to school and still hold the alternative conceptions about everyday phenomena. For example, a tree is not a plant and a spider is not an animal; when substances burn, they always lose weight; plants receive food through their roots; respiration is breathing in and breathing out and so on. Illustrating from Biology, students often describe and explain the living world phenomena like inheritance, various diseases, organic growth and individual development, using the alternative conceptions. The content as well as nature of students' pre-instructional conceptions of the biological world are different from biological science concepts. Knowledge of students' alternative conceptions is critical in determining teaching approaches. As Ausubel (1968) implied, the elicitation of learners' ideas is a prerequisite for modifying and changing their alternative conceptions about how the world works. MCGuigan &Russell (1997) have proposed a basic sequence for constructivist teaching-learning process which includes i) initially set the context, then ii) find out students' ideas iii) select strategies that would help students to develop their ideas and then iv) ensure that students reflect on their ideas and their learning processes. Certain other conceptual change schemes encourage the exchange of ideas, reflection on understandings and modification of ideas on the basis of evidence from testing them.

V. CONCLUSION

To what extent do the approaches sustain the overarching epistemological premises of science teaching is the concern, that we as teacher educators and researchers, have to reflect by looking into our classroom realities. Some of the classroom practices which claim to be using constructivist pedagogy reveal lack of knowledge and understanding of the purpose and the rationale behind using it. The adoption of constructivist teaching in science requires that teachers learn new pedagogic skills of engaging and facilitating learners in meaningful learning processes and transform their classroom roles. The implementation of these strategies also requires new methods of evaluation and assessments. Facilitating learners to inquire into various scientific

happenings, the why and how of those, necessitates an understanding of the nature of scientific knowledge, its methods, and the valid explanations. Lack of this, would result in treating the approaches as mere activities, but not as creating learning environment where children construct knowledge. One can deduce that constructivist epistemologies are more closely related to the components of the nature of science. Teaches must strive to engage students in real investigations and challenge them to create their own problems and solutions. They must encourage and accept children's initiative and preconceptions and engage them in experiences that help in reconstructing their ideas and in critical thinking. Doing so, learning of science can become more challenging, explorative and experiential in nature where the learners play the role of researchers and budding scientists.

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