Science Education beyond Constructivism

H. C. Jain
Regional Institute of Education, Ajmer
Email: hjaint@yahoo.co.in

Abstract- *Constructivism in the last few decades has acquired the status of a grand theory to impart meaningful learning. However, further researches indicate that constructivism does not provide a flawless epistemology; there is difference between how scientific knowledge is created and how it is learnt. Keeping these points in view, a critical appraisal of constructivist approach has been given in this paper. It suggests realistic pedagogy beyond constructivism to be used to study different entities encountered in the world. Further, other approaches viz. Navigationism and Allosteric Model have also been discussed. It is concluded that there is no unique method which can be considered as wholly effective for teaching and learning but the approach has to be manifold.*

Keywords- Radical and Social Constructivism, Epistemology, Realistic Pedagogy, Navigationism, Allosteric Model.

Introduction

Constructivism offered a new paradigm for education in science in the past few decades (Driver and Oldham, 1985) and has acquired the status of a meta or grand theory these days (Tobin and Tippins, 1993). It has met considerable success in its criticism of didacticism and has generated a lot of empirical data which has contributed to our knowledge in understanding the learner and the difficulties in learning of science. NCERT discussion document National Curriculum Framework for School Education (2005) has also recognized it as an important curriculum concern. Basically constructivism has the roots in its reaction against two features dominating science curriculum in 1960's and 1970's viz. an epistemology based on naive empiricism and the developmental stage model signifying limitations of children's capabilities depending upon their age besides the didactic approach being used by teachers. Its salient features include that children construct their own meanings and this is an active and continuous process. Children’s minds are not blank slates on which the teachers can write whatever they like and whenever they like. What is already there in children’s minds matters. For making effective use of these beliefs in curriculum transaction several strategies have been developed leading to the production of wide range of structured techniques which require active participation of the children. Some of important ones are active reading known as DART (directed activities related to text), word association, discussion of episodes of physical phenomena, writing the definition in one's own language, predict-observe-explain sequence, 5E's model and the concept mapping and cooperative learning.

Questions

The first basic question is; does constructivism provide flawless epistemology? Epistemology matters because there is a difference between how the new knowledge of science is created and the existing knowledge is imparted and learnt (Jain 2005). Besides, does constructivist approach consider those aspects which are important ones to Science education such as what we know? Why does it so happen? What can be done with our knowledge? How can we transmit these ideas? Also can we adjudicate when we have multiple answers for the same event/phenomena? Is constructivism a method or referent?

Constructivism: Epistemological Positions and its Limitations

It is seen that constructivism has two well defined epistemological positions (Osborne 1996) viz. radical and social.

1. Radical Constructivism:

Foundation of radical constructivist approach is viability. Whatsoever model, howsoever elegant, is used to explain a phenomenon such as pressure, velocity, gravitational pull etc. should fit with experience and be coherent and good enough to empirical verification by all. Thus, truth becomes a matter of faith. It is a pragmatic view. It means that knowledge is either true or false. In other words, the question 'how do we know?' is replaced by 'why do we talk that way?' In contrast, science has no such position. All knowledge is considered to be tentative and subject to change as we never reach the absolute truth.

At times, we have multiple interpretations for the same event or phenomena or observations but in science we are bound by reality and there are methods (Jain 2005) to decide which of the interpretations is false, incomplete or fallible. It is not clear how the constructivist approach will help the children in deciding which one of the well-established arguments is in line with scientists' description. Besides, the constructivist approach also fails in providing any such mechanism by which any idea or theory can be considered to be more viable than the other. The ideas, that the sun moves round the earth, the heavier objects fall faster than the lighter one, plants get their food from soil etc., obviously are in line with radical constructivists' epistemological view as these are both viable and fit well with experience. Thus epistemology of constructivism fails to consider the issue of adjudication and formulates a mechanism to account for as to which theory is better than the other.

2. Social Constructivism:

Social constructivism takes the view that learning is inseparable from the context of learning. As a consequence, all the activities of science education are reduced to a set of socially constructed activities which are not those of scientists. Contents of science are portrayed as entities of the world visualized socially. Atoms, molecules, electrons, ions, electric and magnetic fields, genes, chromosomes are not considered as products of scientific knowledge but as manifestations or

symbolic entities of this world. Scientific theories don't describe the world but constitute them. Thus, there is a shift from bringing out conceptual changes (Jain, 1994) on the basis of scientific rules, practices etc. to experiences available with human beings. Science is treated as a foreign language vis-à-vis language of gut learning and lay learning because the thematic formations, genres and practical skills of science are different from those of the later. Teachers' role is considered to be that of a facilitator who negotiates through discourse, children's everyday world with that of school science. He won't be expected to raise epistemological issues with children such as how do they know? or why do they know?

Constructivism: Method or Referent

Another problem is whether constructivism is a method or referent (Tobin and Tippins, 1993; Osborne, 1996). Researches in past have shown that it has manifested its power more as a method than referent. But, if it provides effective pedagogic practices, question is how does it lead to internalisation of well-established explanatory scientific models and help in applying them in practice? Constructivism in this regard treats the learners as active cognitive beings or scientists who possess so many well developed mini-theories, misconceptions or alternative frameworks and not as irrational children having no knowledge. They are responsible for their own learning as the meanings are to be formulated and understood in their minds themselves. A new vocabulary leads to a new pattern of language amounting to a new theory. Thus teachers' role is considered by constructivists to be that of negotiating, facilitating, introducing, mediating, constructing, socializing, providing experiences and making the cultural tools of science.

As a referent, there are serious omissions in constructivist approach. There is no reference as to what should be the content and process of science education which such an activity implies. It also does not suggest what propositions can be derived from it and tested.

The most important criticism regarding constructivism is which mechanism should be used that will help the children in constructing their own meanings. For example, the children try to associate their new knowledge with analogies and metaphors (Treagustet al., 1998). Theories of constructivism don't specify any such role. Through intervention studies have suggested creating or generating conceptual conflict (Osborne and Wittrock, 1985) with students' existing knowledge, studies show it to be of limited effectiveness. As an example, if the students are viewing through a lens, how will they be able to explain the image formation unless they are informed about the rules for the same? Thus, it appears that the role of telling, showing, doing and seeing as methods has to be recognized by the constructivists.

Lastly, constructivism as a referent is questionable from two other angles as it merely says that knowledge is made, generated or constructed. On one hand, when a child encounters a new phenomenon what he has to do is to construct it and internalize the same in such a way that knowledge is made. On the other hand, it is not clear as to how new scientific knowledge is

going to be generated/created. Creation of new scientific knowledge and the manner in which old scientific knowledge is learnt cannot be the same (Jain 2005). Constructivists mix up these two issues viz. nature of scientific knowledge and nature of learning. There is no connection between epistemology of science and the way how the knowledge is learnt.

Study of Different Entities

There are three types of entities which are encountered in the world. There is no singular theory to explain them. Rather triadic theories are required. First category of theory comprises classification and predictions about macroscopic objects such as chair, moon, spring, ball, animals, plants, food items, organs etc. These are accessible to sensorimotor experiences. Their recognition, behavior etc. and in case of many other visible objects classical kinematics are sufficient to understand their mechanism. Second category of theory includes understanding about such entities which are accessible to our senses and measurable through instruments. For example, a very distant object can be viewed using a telescope; bacteria, virus and crystal structures through a suitable microscope; particles striking the earth can be detected using nuclear detectors; spectra can be seen using suitable spectrographs; smaller objects can be measured using Vernier caliper and micrometer screw gauge; smaller time intervals can be recorded using crystal clocks and so on. All such entities are representations of those physical/biological systems which were not seen/measured initially using our senses. Third category of theory includes explanations about those objects or entities about which there is no direct evidence for their existence. For example, gravitons, photons, quarks and gluons can only be understood using mathematical formulation, origin of cosmic rays, molecular motion, electron moving in orbits etc. can be understood using several hypotheses, and so on. However, in some cases these entities with advanced technology, at some time may also form a part of second category of theory as it happened with the entity like virus which was not initially seen but later on electron microscope made it possible.

Pedagogies beyond Constructivism

Realist pedagogy (Osborne, 1996) in order to teach all the categories of entities, can be used to develop early science education in steps. Firstly, attempt can be made to build on and extend children's experiences of macroscopic phenomena. Secondly, introduce them with the descriptive scientists' language and theoretical frameworks. Thirdly, the ideas of categories 2 and 3 can be introduced. Such a strategy will help the children to generalize their experiences and perceptions in the light of scientists' views. Besides, this approach will encourage activities of observations pertaining to microscopic phenomena and can be used to lead the children from category 1 to category 2 in the natural course. For example, falling of objects towards earth, observation of expansion of solids, liquids and gases, disappearance and appearance of liquids on heating and cooling, viewing of objects in light, human beings inhaling oxygen and exhaling carbon dioxide, springs and rubber stretch etc. can all be accordingly associated with the scientists' terms viz. gravitation, linear and volume expansion, evaporation and condensation and the mechanism of

seeing, respiration and the pattern of stretching respectively. From here science education can move to entities of category 2 for which instrumental evidence is available. For example, use of microscope can lead to the study of bacteria, cells, tissues, internal structure of objects like plants and parts of human body, use of telescope can lead to the study of distant objects, use of compass needle can lead to the detection of magnetic property of materials and earth behaving as a magnet, use of thermometer can give the idea about the degree of hotness and so on. Such observations through instrumentation will help in relating the existence of entities of category 2 with those of category l, which are easily accessible to children, making use of direct references, analogies and metaphors to construct models and representations. After completion of this stage, concepts of entities of category 3 which are human abstractions such as speed, velocity, current, voltage, energy, momentum etc. can be constructed making use of references of motion, brightness of bulbs and other appropriate causal relationships. Cognitively, such an approach can be quite useful to envisage and manipulate human abstractions for which there is no direct referent. Connections with the known entities will facilitate in constructing the new knowledge. Also the curriculum developers can decide about the nature of content for which constructivist epistemology says nothing. Accordingly, unless the children are equipped with a wide range of factual information using macroscopic observation followed by those using instruments and the mechanism behind all of them, they should not be taught with ideas pertaining to relativity, quantum mechanics, molecular biology etc.

Navigationism

Brown (2005) has pointed out that in the present technological era, there is an ocean of available information and knowledge. It is therefore, necessary that the focus of training the learners should be to find, identify, manipulate and evaluate the same and then integrate it in the world of work and life. In turn, the learners should make its use in solving the problems and communicate the knowledge to others. Teachers' and educators' role is therefore having to be that of coaches and mentors within knowledge era and not merely that of facilitators. In other words, teachers should be the source of skills and competencies for helping the learners in navigating the available knowledge from different sources. This is a paradigm shift from learning facilitation in case of constructivist approach to mentoring and coaching through guided research/supported enquiry. This later approach has been termed by Brown as navigatiomism/evaluationism as it will help the learners to come closer to scientists' point of view vis-à-vis their concepts.

Allosteric Learning Model

Geordan (2012) has pointed out that constructivist approach considered to be a model approach is very crude in educational practice. His view is that in constructivist approach learning is to be facilitated by the existence of 'cognitive bridges' so as to render new knowledge significant in relation to pre-existing structure. He suggests that to gain new knowledge three conditions must be satisfied. Firstly, more general concepts must be available which must be differentiated progressively amongst themselves during learning. Secondly, new knowledge should be

introduced only when the preceding one has been masterd. He has given the term 'consolidation' to this process. Thirdly, similarities and differences between the old and new knowledge should be perceived as 'integrative conciliation'. Looking to these parameters, which are beyond the limits of constructivist models, the following approach known as 'allosteric model' should be attempted:

- On what learning means in several situations.
- On the mechanisms at work.
- On the conditions/situations which facilitate learning.

It is expected that such an approach will reconcile the paradoxical and contradictory aspects in all learning.

Conclusion

Above discussion suggests that there is no unique method which can be called as wholly effective for teaching and learning. There can be a wide range of instructional procedures. To suggest that constructivist approach provides an improved learning strategy for all pupils is erroneous. Rather it offers a flawed epistemology which represents science as it is practiced. Though, it is correct that all forms of scientific knowledge are human construct, but it has predictive validity which the scientists go on confirming time and again and that enhances our knowledge of objects which initially seem to be tenuous. But constructivists' focus on human and social construction of knowledge always requires it to be viable and there is no scope for adjudication of different claims of knowledge. Besides, there are issues as discussed above which demand that in the absence of telling, showing, doing and demonstrating students will not be able to conceive the scientists' ideas of varying nature. Also, focus should be to ensure that the learners acquire different basic and integrated process skills and also navigating skills for a navigationist learning paradigm. Teaching learning process should take into account varying situations in different contexts for imparting meaningful learning. Teachers' role has to be that of a coach or a mentor and not merely the facilitator so that learners develop knowledge in line with scientist views, principles and theories. However, all these ideas do not imply or undermine the importance of constructivist outcomes. These will remain just like behaviourism has not ceased to exist but focus has to be manifold.

References

Brown, T. H. (2005). Beyond Constructivism: Exploring Future Learning Pradigms. *Education To-day.* 1-11.

Driver, R and Oldham, V. (1985). A Constructivist approach to Curriculum development. *Studies in Science Education*, 13, 105-122.

Giordan, A. (2012). *The Allosteric Learning Model and Current Theories about Learning.* Retrieved from http://cms.unige.ch/ldes/ wpcontent/uploads/2012/07.

Jain, H.C. (1994). Towards a Conceptual Change Perspective. *Teacher Today*, 36(3), 1-6.

Jain, H.C. (2005). Conceptions about Epistemology of Science. *Edu tracks*, 4(5) 31-35

Jain, H.C. "Scientists and Scientific Method". *Eductracks*, (2005): 4(9), 25-29.

National Council of Educational Research and Training (2005). *National Curriculum Framework for School Education* - 2005. New Delhi: NCERT

Osborne, J.F. (1996). Beyond constructivism. *Science Education*, 80(1), 53-82.

Osborne, R.J. and Wittrock, M. (1985). The Generative learning model and implications for Science education. *Studies in Science Education*, 12, 59-87.

Tobin, K. and Tippins D. (1993). Constructivism as a referent for teaching and learning. *In K.Tobin (ed.) The practice of constructivism in Science Education, Hove, Lawrence Erlbaum.*

Treagust, D. F., Harrison A. G. and Venville, G.J. (1998). Teaching science effectively with analogies: An approach for pre-service and in-service teacher education. *Journal of Science Teacher Education*, 9(2), 85-101.