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Pedagogical Shift in Science

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Abstract:

Pedagogy of science deals with strategies of teaching-learning, organizing classroom experiences, knowledge about preconception of learners and transacting the concepts to diverse groups of learners relating with their preconception, so that they can assimilate and accommodate new information to make meaning of it. Teachers need to recognize that with the creation of new knowledge all over the world, socio-cultural and economic conditions of our society change, new opportunities of work arise and aspiration of people grow. This dynamism of society must be reflected in the pedagogy of science. Today's pedagogy gives value to the voice of learners and their questions, their abilities of making argumentation and justification, synthesizing and analyzing knowledge and their involvement in the process of inquiring science in a collaborative set-up rather than their ability of rote memorization. Consequent to the implementation of NCF-2005, a shift in pedagogy is taking place in our country. There is also a shift in our understanding of process of learning and about learners in the classrooms.

Key words: Pedagogical shift, Science

INTRODUCTION

Today's pedagogy gives value to the voice of learners and their questions, their abilities of making argumentation and

justification, synthesizing and analyzing knowledge and their involvement in the process of inquiring science in a collaborative set-up rather than their ability of rote memorization. Consequent to the implementation of NCF-2005, a shift in pedagogy is taking place in our country. There is also a shift in our understanding of process of learning and about learners in the classrooms.

The nature and origin of knowledge is going through continuous debates. It has been repeatedly emphasized that these developments should translate themselves in ways and forms making them accessible to learners. Foundation of modern Indian education was laid down by the thinkers like Aurobindo Ghosh, Rabindra Nath Tagore, Mahatma Gandhi, Maulana Abul Kalam Azad, Sarvepalli Radha Krishnan. Almost all the pedagogies related with content knowledge deal with learning and knowledge. Thus, to make any alternate pedagogy successful and meaningful in a given context, there is a need to understand the epistemic and epistemological dimensions of learning. Hence, there is a need to understand the nature of learning and nature of teaching with reference to science. Teaching– learning is a collaborative process in which sometimes teacher may work as a student and sometimes student may work as a teacher and they share knowledge with each other.

HISTORICAL BACKGROUND

Scenario from 1950–1980

Until the 1950s, researches on teaching focused on two themes— firstly, the method 'experiments' where researchers compared the relative merits of using one method of teaching a particular subject with another method and secondly, exploring the personal characteristics of a good teacher. By the 1960s, it was increasingly recognized that teaching could not be described or prescribed in terms of standardized methods. It was also accepted that teachers could not be distinguished by

any kind of distinctive personality alone. It was realized that to understand teaching, one needs to study what happens in the classroom. During 1960 to 1980, the movement for knowing how students learn science began. Bruner (1961) for the first time identified the characteristics of a concept and proposed the concept attainment model. Bruner model advocates that a child is said to have attained a concept, if she can apply the concept in unfamiliar situations and arrive at valid conclusions. 'Discovery learning' was also pioneered by Bruner which was used as the foundation for curriculum development during 1960s to the 1980s. He emphasized on helping students 'how to learn'.

Ausubel also tried to understand the learning process. He was among the first to describe the importance of the knowledge students carry to the classroom. He proposed that students are not devoid of ideas. Their experiential knowledge have a profound effect on how students learn in the class. Meaningful learning occurs when new information is linked with existing concepts and integrated into what the learner already understands. Students can make connections between what they learn in science classrooms and what they already know. In order to understand how children learn science, it is important to consider the development of children's cognitive abilities and skills.

Through extensive and intensive empirical evidences, Piaget proposed 'stage dependent' theory where the mental growth of a child goes through four discernible stages. These are hierarchical stages. He associated each stage with a particular age range. The age associated with each stage is individual dependent, i.e. few may not reach the last stage of cognitive development. The stages are (i) The sensory motor stage (ii) The pre-operational (0–2 years) stage (2–7 years) (iii) The concrete stage (iv) The formal stage (7–11 years) (11–15 years) Piaget believed that learning is strongly influenced by the learners' developmental stages. Learners move through identifiable stages of physical, intellectual, emotional and social

growth that determine what can be learned and with what depth of understanding. Learners learn best when they are at the proximal stage of development.

According to Piaget, 'organization of concepts in the mind of a learner goes through four cognitive processes—schema (organized mental representation of thought), assimilation, accommodation and equilibration'. These processes are not specific to any stage of cognitive development. An individual expects to understand each new experience in terms of what she/he already knows by assimilating the experience. Confusion occurs when a learner is unable to assimilate a particular experience to the existing ones. To reach equilibration a learner brings meaning to a new experience through the process of assimilation and accommodation. This process requires an individual to restructure the existing knowledge or reject the existing knowledge and construct entirely new knowledge. These two processes, that is, assimilation and accommodation are important mechanisms in understanding learning of science.

Lev S. Vygotsky argued that learning is social in nature. It is more important to know what a child is capable of learning with good teaching-learning process. He believed that learning can be structured, so children become active learners while teachers or other adults use their advanced knowledge to meaningfully guide the learning. A child learns through social interaction and from peers, older children and adults who know more and have more experience. By comparing their understanding with that of others and by examining their knowledge against other's knowledge, learners develop new knowledge. Vygotsky believed that when aided, a child can learn more than if student is left unaided. The difference between what a child can produce unaided and what the child can produce with an aid or good instruction is called the zone of proximal development. Thus, when a teacher plans for instruction, learner should be aware of the zone of proximal

development for the child, so that her optimum potential can be realized.

POST 1980 SCENARIO

The researchers found that in teaching process, the teacher is not important, The learner is not important, but the learning process is important which measures the success of the teaching-learning process. In this process they noticed two important aspects like (i) ascertain what the child knows and (ii) engage her in teaching– learning accordingly. During 1980s and 1990s, constructivist movement gained momentum. A number of studies were conducted by Posner (1982), Driver (1994), Novak (1984) and others on 'how children construct knowledge, and how teacher can provide interventions to help children construct their own concepts.' The study provides some of the basic characteristics of constructivist approach of teaching-learning: No child enters a class devoid of concepts. Learning implies the reorganization of prior concepts of the learners. Concepts cannot be instructed, but constructed. Every child constructs his knowledge on the basis of her existing knowledge

Pedagogical Shift from science as fixed body constructing of knowledge to the process of knowledge

Earlier, nature of knowledge in general and nature of knowing in particular was considered as a fixed entity. However, in the contemporary understanding of nature of knowledge and nature of knowing, these are dynamic entities. Thus, the pedagogy which teachers use to construct knowledge through diverse learning strategies includes previous experiences of the learner, their socio-cultural and economic background along with the content knowledge rather than overwhelming emphasis on the psychological characteristics to the individual learner. Till recently, the main purpose of studying science was perceived as 'acquiring' scientific knowledge. Now, there is a

shift in perception regarding this purpose. This shift is tilted towards 'construction' of scientific knowledge, not the passive acquisition of factual knowledge. Construction of scientific knowledge concerns knowledge of 'how to do things' scientifically (here, doing is not confined to manual activity only, it could be mental activity also) and, perhaps, that is why scientific knowledge is always the result of a constructive activity. Therefore, the fundamental difference between the acquisition and the construction of scientific knowledge is passive receipt of the knowledge, and active involvement and critical examination based on critical thinking on the part of the learners. Shift in pedagogy of science from a fixed body of knowledge to the process of constructing knowledge has many dimensions. It includes a shift in our understanding of nature of science; nature of knowledge; learners, learning and teachers; assessment; science curriculum; scientific method and scientific inquiry; importance of critical pedagogy; approaches to planning; various aspects of inclusive education; etc. In order to understand pedagogical shift in science, it is important to have a brief overview of all these aspects related with teaching–learning in science

Pedagogical shift: Nature of science

Unlike earlier beliefs and understanding no single method exists that can be termed as method of science, rather, there are many features common to scientific enterprise that can be seen as scientific approach which may have explanations supported by empirical evidences and testing of result in terms of its efficacy in nature. The knowledge in science is subject to change i.e. it is tentative in nature. This tentative nature of scientific knowledge interestingly does not make it unreliable. There is always an element of subjectivity in the development of scientific knowledge, even if teachers consider that science always strives for objectivity. Socio-cultural factors also have impact on nature of science. Role of creativity, observation, inference, etc. have been understood to be important in the

development of science. In simple terms, the scientists collect relevant data and use evidences to explain ideas under consideration. They use their own perspective to guide themselves about problems. Scientists can change their ideas on the basis of contemporary development in their fields and create new ideas. In order to understand science, teachers must know the manner in which knowledge is constructed over time as well as the method used to validate that knowledge and the place of science in society.

Pedagogical shift: Knowledge

Science is an enterprise that has evolved over many thousands of years and continues to evolve. Our understanding of knowledge has shifted from a 'static entity' to a 'dynamic entity.'(Loughran, J.; Berry,A. & Mulhall, P.2005) Considering knowledge as a static entity to be transferred to learner's mind makes her passive receiver of knowledge without engaging in thinking and questioning. The knowledge is actively constructed by learner and cannot be passively received. So learning is something done by the learners and not something that can be imposed on them. Knowledge can be conceived as experiences organized through language into structures of concepts, thus creating meaning which in turn helps learners to understand the world they live in.

Pedagogical shift: Learners, learning and teachers

Learners come to the learning situations in science with their existing ideas about phenomena, not just around them but across the real physical realm within their reach. Some of these ideas are relatively temporary and unstable; many other are deep-rooted, well developed and difficult to be changed. Although these ideas are individual in nature, there are many commonalities. Some of these ideas are socially and culturally embedded, they are supported by language and metaphors and work as tools to understand many phenomena (Agrawal, R. & Chawla, (2009). These ideas many a times are in contrast and

odds with the scientifically accepted ideas, and are hard to change. Thus, for an effective pedagogical design, a teacher has to take care of the existing ideas of the learners and the difference in nature of their ideas with the scientific explanation of those ideas.

There is a major shift in the teacher's role from where learner assumes a position of centre stage as a source of knowledge as to being a facilitator of transforming knowledge and as a supporter in enhancing learning through multiple exposures, encouraging the learners to continuously achieve their educational goals. Learner is no longer considered as custodian and manager of all teaching-learning processes. Learners have now taken the central stage. Their viewpoints are sought and valued. Learners get motivated to learn when they discover their own ideas, asking their own questions and trying to find out answers for themselves

Pedagogical shift: Assessment

The purpose of assessment is necessarily to improve the teaching learning process and to be able to review the objectives that have been identified for different stages of learning. Needless to say, this does not mean that test and examinations will have to be conducted frequently. On the contrary, routine activities and exercises can be employed effectively to assess learning. In addition to learner's achievement in various subject areas that can be tested easily, assessment needs to encompass attitudes to learning, interest and the ability to learn independently. Furthermore, to test all the learners through a written test of the same type in all subjects is unfair to those whose verbal proficiency is superior to their writing skills or those who work more slowly but with deeper insight. NCF-2005 recommends a shift in modes of assessment by making it more flexible. It emphasizes various modes of assessment including all meaningful aspects of performance, e.g. activities, experiments, journals, illustrations, oral presentations, peer

evaluation, self evaluation, group work assessment, models, portfolios, and other artifacts of learning.

Pedagogical shift: Science curriculum and scientific inquiry

Most of the science curricula of 1960s and 1970s suggested that by doing science, students will automatically come to understand the nature of science and scientific inquiry. This approach was adopted and hands-on activities and process skills instruction were included in the science curricula. In that approach, it was assumed that scientific inquiry is related with the development of process skills such as observing, inferring, classifying, predicting, measuring, questioning, interpreting and analyzing data. By assuming that the so-called fixed set and sequence of steps (generally known as scientific method) is a representation of multiplicity in terms of the approaches of inquiry followed by scientists, one important understanding about scientific inquiry was missing. It was about engaging learners in scientific investigations to find answers of self indentified questions. In order to deal with this gap in the implicit approach to scientific inquiry, historical approach was suggested. Historical approach assumed that incorporating history of science will ensure that students understand nature of science and scientific inquiry. Researchers have shown that both these approaches (implicit and historical) have failed in developing the understanding of nature of science and scientific inquiry among learners. There is another approach which suggests that in order to improve students' views of scientific endeavour, learning of scientific inquiry should be well-planned and cannot be expected as a side effect of various approaches of teaching learning science. This is sometimes referred as explicit, reflective approach. It is important to mention here that the contemporary view of scientific inquiry suggests that the questions which are asked or are to be answered guide the scientific inquiry in terms of methods that are used by our scientists. Thus, the scientific inquiry varies widely within

scientific disciplines and also across various disciplines. Inquiry as a teaching-learning approach will thus mean placing learners in situations that are very similar to something that scientists experience during the daily journey of scientific endeavour.

Pedagogical shift: scientific method to science as inquiry

According to Nobel Laureate in Physics (1993) Russell A. Hulse, scientific method is an approach to seek knowledge in which scientists weave their ways back and forth as they inquire. They wonder, question, gather data and analyze. The question that strikes mind of a scientist is treated as problem. Learners guess and think about several possible answers and solutions to the problem. Learners' benefits by knowing what others have already discovered and use it as a framework on which learners builds her/his knowledge. Thus, scientists suggest answers to the question being investigated in not just very personal way, but in participation with what is known as scientific community. This is how a hypothesis is formulated. Hypothesis formation is a creative process embedded in a holistic framework. In her/his work, a scientist may have to depend upon the findings of others and ultimately a problem may be solved by the accumulated efforts of several scientists.

Observation

Science is empirical and facts are sacred to scientists. Facts are observable. So science starts with one observation and ends with more observations. It is important that experiments and activities must generate opportunities of observations to learners. While carrying out experiments and activities, asking the class a simple question skillfully, "What do you observe?" may provoke thinking and may generate divergent answers since it is open-ended. If the teacher draws attention of learners towards few questions, and later prompts students for more observations, such questions generate guided observation.

Hypothesis

Humans are naturally curious and like to find explanation for observations made. Explanations are given using the known facts. But some observations cannot be explained since teachers do not have 'facts' to apply. In such cases some models (theories) are proposed to explain the observed set of facts. These theories invoke the 'unobserved' to explain the observed. Theories require test of experimental verification before being accepted as laws. For example—kinetic theory, atomic theory, etc. Similarly some observations are reasoned out using some intelligent guesses. They are called hypotheses. These hypotheses may only explain a few observations or most of the observations. The one which explains most observations most satisfactorily is chosen as the best hypothesis.

Experimentation

Experiments should be integrated with the theory part of the science. It should not be treated in a piecemeal manner. Experiments on displacement reaction may be carried out with the traditional and constructivist approach.

Data Collection:

Most of the explanations/solutions are obtained by doing experiments. In cases where experimentation is not possible the data is collected using reference/resource materials. A survey method involves such a collection of data and observing a pattern among the data, so that a rule (concept) may be formed. The source of the data has to be reliable or authentic. The conditions also have to be specified under which such a data is collected, because the validity of generalization depends upon the validity of the data.

As seen above, NCF-2005 envisages teaching-learning of science in schools to be learner-centered and process and inquiry oriented. The teacher preparation programmes can also take a message from these examples to encourage construction of experiential learning environments. National Curriculum

Framework for Teacher Education (NCFTE, 2009) also recommends adoption of process-based teacher education. The student-teacher should also be provided with ample opportunities for self-learning, reflection and assimilation. In addition and more importantly, there should be scope for articulation of new ideas, ability to enhance thinking and work efficiently in groups.

Democratizing science learning: Critical Pedagogy

Critical Pedagogy is child-centered pedagogy. It facilitates collective decision-making through open-mindedness and by encouraging and recognizing multiple views of the learners. It emphasizes to move beyond authoritative role of the teacher by promoting sharing of power with the learners by encouraging critical thinking and commitment to democratic form of interaction. It is a pedagogy that takes into accounts the experiences and perception of learners and helps them to learn in a fear free and independent form. In the context of critical pedagogy, NCF-2005 (NCF, 2005) recommends following guidelines

- Participatory learning and teaching, emotion and experiences need to have a definite and valued place in the classroom.
- Children need to be made aware that their experiences and perceptions are important. They should be encouraged to develop the mental skills needed to think and reason independently. It is important to value what learners learn out of school— their capacities, learning abilities and knowledge base and bring them to schools in order to further enhance the learning process. This is all the more important for the children of underprivileged class.
- Children are critical observers of their own conditions and needs. They should actively participate in discussions and problem solving related to their education and future opportunities.

- Children are not just young people for whom adults should devise solutions. Teacher's engagement with children is critical in the classroom, because it has the power to define whose knowledge will become part of the school-related knowledge and whose voice will shape it.
- When children and teachers share and reflect on their individual and collective experiences without fear of judgment, it gives them opportunities to learn about others who may not be a part of their own social reality. This enables them to understand and relate to differences instead of fearing them. If children's social experiences are to be brought into the classroom, it is inevitable that issues of conflict will need to be addressed. Conflict is an inescapable part of children's lives. To use conflict as a strategy is to enable children to deal with conflict and facilitate awareness of its nature and its role in their lives.

Critical pedagogy and role of teachers

- The role of teachers is to provide a safe space for children to express themselves, and simultaneously to build in certain form of interactions.
- Teachers need to step out of the role of 'moral authority' and learn to listen with empathy and without judgment, and to enable children to listen to each other.
- While consolidating and constructively stretching the limits of children's understanding, they need to be conscious of how differences are expressed.
- An atmosphere of trust would make the classroom a safe space, where children can share experiences, where conflict can be acknowledged and constructively questioned, and where resolutions, however tentative can be mutually worked out.

Pedagogical Shift: Planning Teaching-Learning Experiences

Children are critical observers of their own conditions and needs. They should actively participate in discussions and problem solving related to their education and future opportunities. (NCTE, 2009). Children are not just young people for whom adults should devise solutions. Teacher's engagement with children is critical in the classroom, because it has the power to define whose knowledge will become part of the school-related knowledge and whose voice will shape it, conceptual change like paradigm shift (Ergin, I. 2012).

Planning teaching-learning: Before shift

What will I be teaching?
How much do I know the syllabus?
How do I prepare the students for the upcoming exams?
What serialization of the concepts should I consider?

Planning teaching-learning: After shift

Following are the respective changes in the questions that need to be answered in order to plan teaching-learning process in science

What are the learning needs and previous experiences of my learners?

How much I am acquainted with the learning needs of my learners?

How do I facilitate each learner's learning?

How do I incorporate the differential learning pace of my learners?

The shift to the new frameworks also means that the teacher obviously has a lot of liberty in choosing the planning approaches and strategies. This liberty of planning provides flexibility to the teacher to consider students' learning needs; their existing concepts; the context of their learning; local and national needs; nature of curriculum; etc. in designing teaching-learning experience.

Planning teaching-learning: Examples

Some of the shifts can be seen in the following examples in the learning area of Properties of Matter is studied by student centric approach (Sarac, H. & Balta, N. 2016). Statement-1. A teacher can teach the properties of matter on the basis of previous knowledge of students about solids, liquids and gases taught during previous classes. Statement-2. A teaching-learning process can be designed in the learning area of Properties of Matter based upon some understanding of solids, liquids, and gases as explored in previous classes. This lesson needs a brief introduction of matter. It is clear to all there is difference in the two statements above. Whereas in the first statement the assumption is about pouring knowledge into the mind of students, the second statement is about designing teaching learning experiences for the students which are based on their previous explorations to facilitate the meaning-making process.

Pedagogical Shift: Inclusion

A policy of inclusion needs to be implemented in all aspects of teaching learning of science. A pedagogical shift is required to identify diverse capabilities and talent of all learners**.** Let us now discuss it in detail.

Science curriculum

Equal opportunities and full participation to all learners including learners with special needs, and learners learning with different paces should be provided in the theoretical and practical activities conducted in science classes. Through adaptation of the curriculum (what learners learn) and modification of the approaches of teaching-learning (how learners learn), access to science curriculum can be made possible for all these learners. Accommodations in the general curriculum do not change the learning level of the curriculum or the performance criteria. With accommodations, the learners are working on the same learning objectives and content as the

other learners; however, how the learners learn and the ways they produce evidences of what they have learned may be different from that of their peers i.e. the pedagogical approach of teaching integrated science(H.Sara & Wishartb, J., 2008),.

Diversity in class

Inclusion is centrally a pedagogical issue, since it creates the most significant barrier to learning and exclusion for many learners. These barriers to learning arise from various interlocking parts of the curriculum and pedagogy, such as the content of learning programmes; the language and medium of teaching and learning; the management and organization of classrooms; learning style and pace; time frames for completion of curricula; the materials and equipments, that have been available for conduct of theoretical and practical sessions; and assessment tools and techniques.

It is a clear pedagogical principle that teacher should use a variety of approaches and strategies that promote meaningful learning, active participation of all learners, recognition of their knowledge and previous personal experiences, autonomy in their learning process and self control and collaboration among learners.

The pedagogical shift in science education should be based on giving respect and value to individual differences and providing opportunities for scientific exploration, manipulation, experimentation and discovery of scientific phenomena which ultimately enhance the personal development of every learner.

Approaches

The educational approach should be based on heterogeneity in the classroom instead of homogeneity. The educational approaches based on homogeneity have taken us to perceive diversity from normative criteria. (H.Jan,; Van, H. & Nico Verloop, 1998) Those learners who do not confirm to standard established norms are considered different having difficulties

and anomalies and engaged with differentiated programmes and different approaches

Information and Communication Technology (ICT)

ICT can be made accessible to the learners with special educational needs by innovations and adaptations in the basic functional units of ICT such as 'microchips' and 'software packages' (Abu Naji, M. (2008). Most of the information is disseminated either in the visual or in audio format restricting its accessibility to students with sensory impairments. For exploration and manipulation of electronic gadgets and hardware, high level motor planning, coordination and execution are required in the individual which is lacking in most of the learners with special needs like in cases of cerebral palsy and other neurological and locomotor disabilities; dysgraphia, dyspraxia, mental retardation, visual impairment, mental illness, leprosy cured and in multiple disabilities conditions.

Professional development

Although pre-service and in-service teachers' training programmes are now having contents related to education of learners with special educational needs, the teaching in inclusive classrooms where such learners are also studying is not properly practiced in a real inclusive setting. (Aina, H.; Jacob Kola, 2015) Due to this reason, the educators lack proficiency in different aspects of teaching–learning like attending the needs of diverse groups, curriculum adaptation, transaction of contents as per the needs of all learners, differential evaluation, etc. Preparing Individualized Education Plans (IEPs) and incorporating these IEPs in parallel to regular classroom teaching learning is another big challenge for the teachers. Special teachers are trained in education for particular types of disability and in the case where special teachers for other disabilities such as for visual or hearing disability are placed, may not find themselves skillful for

meeting the educational needs of the learners with other types of disabilities

CONCLUSION:

The movement towards pedagogical shift in teaching-learning of science can be augmented by critically focusing among the teachers and learners, the constraining influences and promoting collaborative efforts aimed at overpowering them. For any qualitative change from the present situation of science education, a shift in pedagogy from a fixed body of knowledge to the process of constructing knowledge is urgently required. It is important to encourage inventiveness, creativity and critical thinking in learner rather than developing competency. Rote memorization should be discouraged. Inquiry skills should be supported by language, design of conducive learning environment and laboratory work. It is also important to allow students making errors and mistakes as it are an integral part of the learning process and remove the fear of not achieving 'full marks' or 'first prize'. Participation of all learners in various aspects of teaching-learning should be ensured. Schools should place much greater emphasis on various curricular activities aimed at stimulating investigative ability, inventiveness and creativity even if these are not part of the external examination system. Teacher should consider learners an active member of a group of persons who makes conscious efforts for updating the pedagogy, so that it is relevant to changing societal needs and personal needs of learners. Providing flexibility to the work of teacher and support of school authorities is essential to work towards pedagogical shift. Teacher should articulate their ideas to administrators.

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