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Remarkable Outlook of Science Process Skill

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In 1914 the journal namely 'Nature' concluded that during the second world war pure & applied science plays a conspicuous part provided a sense of urgency in general & a medium for revealing utility of science. During that time science became specialized & required a new educational system with its curriculum. By the beginning of the war, the matter became a rallying cry for the restructuring of the entire educational system.

In 1917, a group of eminent Cambridge professors & alumni published 'Science & the Nation' to enlighten the lay public on the importance of Science. They attempted to illustrate that pure science was not merely a purely academic subject but was the source of many practical applications that brought national strength & prosperity.

At the middle of the 19th century, science was not widely viewed as knowledge that was worthy of study for the majority of students. The idea of "science for all," however, did begin to take hold as the 19th century drew to a close.

Struggles for recognition of scientific profession started in the 19th century. Wan Zuoyue in his article focused on that during the first two decades of 20th century difficulty regarding science is more institutional than individual. Prior to 1940's the form of Science Education in high schools was predicted on the idea that science had something of value to offer students & general public.

The body of scientific knowledge, which is the result of the quest for comprehension and explanation through the development of fundamental principles, is called the 'content' or 'products' or 'major concepts' of science. The method used by scientists for acquiring the body of knowledge is known as the scientific method or method of inquiry or processes of science. The scientists use experimentation and observation as the basis of developing conceptual schemes. The development of conceptual schemes by experiment and observation and the premise that these conceptual schemes lead to further experimentation and observation are considered as the fundamental aspects of the nature of science.

This cyclic nature of the genesis of conceptual schemes from observation and experimentation and the use of them to stimulate further observation and experimentation is also found extensively in the writings of scientists and philosophers of science.

From the regularities found in the experiment, conceptual structures are evolved. The value of these conceptual structures depends on its effectiveness to predict further behavior of nature. These predictions serve as the basis for further experimentation and observation. And so the

scientific structure appears to be a self-renewing, never ending one which continuously builds new conceptual structures through experimentation on, and analysis of the environment

The terms such as, thinking skills, scientific thinking, reasoning skills, cognitive development, critical thinking and logical thinking have been considered as related to science process or processes of scientific inquiry. Upon examination, these terms contain some common elements.

The National Council of Educational Research and Training, (NCERT) while planning the integrated science curriculum for the middle school students, identified the process approach as one of the core elements of the course. While discussing the philosophy of the integrated curriculum, the document integrated Science Curriculum - an introduction (NCERT, 1982) states: " a science curriculum must stress more on these processes than the products of science. The knowledge of the product is useful in understanding the processes of science and for concretizing the processes for pedagogical use. But understandings of the processes are useful both for daily life as well as in furthering scientific knowledge".

Science from Natural Philosophy to Compulsory Subject:

In Eighteenth century Science introduced as a Natural Philosophy into schools aiming at the biology in relation to human welfare. Around in 1872 Natural Philosophy disappeared from American schools and to be replaced by high school physics with filled text including algebra & mathematical formulae along with abstract line drawings. During the first half of century, in response to a multitude of pressure business & industrial demands, environmental problems, health concerns school biology diverged from university biology. In 18th century aim of Biology teaching changed from Biology for the sake of Biology to Biology in relation to Human Welfare.

From above picture it is revealed that at the start of the century Science familiarized as a Natural philosophy and then renowned as physics with changing aim for human welfare. Following is the topology used for Science Process Skills by various experts, groups and Committees.

Table No. 1 Topology related to Science Processes & skills mentioned by various institutions/ persons

Sr. No.	Name of Institution/ Person	Topology used	Skill mentioned
1	Dewey (1910)	Steps Process of Thinking	Felt difficulty, definition, suggestion of possible solution, Development by reasoning, Further observation leading to acceptance or rejection
2	Karl Pearsons (1937)	Steps of Scientific Inquiry	Identification of problem, Observation, Hypothesizing, Testable predictions, testing of hypothesis, hypothesis accepted or rejected
3	Good (1945)	Scientific Method	Identification of problem, survey, hypothesis, testing, hypothesis accepted or rejected
4	Dressel et.al. (1949)	Elements of scientific thinking	a. recognize and solve problems b. recognize hypotheses and select methods for testing them c. critically evaluate experimental procedures,

			data conclusions and implications and d. appraise real situations
5	Burmster (1950)	Abilities for scientific thinking	Recognize Problem, Delimit problem, understand experimental method, organize data, interpret data, evaluate conclusions, make generalizations
6	Oburn (1956)	Scientific Investigation	Defining problem, collecting, organizing and interpreting evidence, selecting & testing hypothesis, formulating conclusions
7	Burton et.al. (1960)	problem solving	a. recognizes and defines problem b. formulates adequate hypothesis c. makes pertinent selections d. draws valid conclusions e. applies conclusions
8	AAAS (1968)	Basic and Integrated processes	Observing, Using space time relationship, Classifying, using numbers, measuring, communicating, predicting, inferring, Controlling variables, interpreting data, formulating hypothesis, defining operationally, Experimenting
9	Anderson (1970)	Science as an activity	Problem is stated, hypothesis formulated, experiment conducted, data collected, conclusion is drawn
10	Klopfer (1971)	process of scientific enquiry	Observing and Measuring, Seeing a Problem and Seeking Ways to Solve it, Interpreting Data and Formulating Generalizations, Building, Testing and Revising a Theoretical Model
11	Hurd (1971)	Processes represents the intellectual mean	Organization of observation, established data, focuses on a problem, interpret rational event
12	Tennenbaum (1971)	Science Processes	Initiation, Collection of Data, Processing of Data, Conceptualization of Data, and Open mindness
13	Nay et.al. (1971)	Scientific inquiry	initiation, collecting of data, processing of data, conceptualization of data and open endedness
14	Riley (1972)	Science Inquiring Skills	Identifying and controlling variable, interpreting data. predicting and inferring
15	Streven and Kothari (1972)	conceptual processes	Classifying, measuring space-time relations, communicating. inferring, observing, quantifying, abstraction making, model making, hypothesis making, listing, theorising, predicting, replicating, extrapolating, generalizing etc.
16	Harry (1972)	process skills	Observation, description, classification, analysis, inference, measurement, prediction , communication, formulating hypothesis and interpreting data

17	Esler (1973)	process of science	Communication, Prediction and controlling variables
18	Kerlinger (1973	process of reflective inquiry	troubled situation, hypothesis, reasoning and deduction, observation test and experiment
19	Doran et. Al. (1974)	processes of science	observation: measurement, classification, experiment, communication, prediction and
20	Loretta and George (1976)	Process abilities	classification, inference, prediction & and hypothesis formation
21	Bhandula et.al. (1979)	Scientific skills	observing, classifying, measuring, communicating and recognizing number relations.
22	Donelly (1985)	Science Processes	purposeful observation; analysis-synthesis: selective recall; hypotheses: verification by inference and experiment; reasoning (by different models) and judgement.
23	Poulose (1987)	scientific process skills	initiation. manipulation and open-endedness
24	Bhatt(1988)	Processes	observation to prediction
25	UNESCO (1992)		Observing ,Raising questions ,Hypothesizing Predicting ,Finding patterns and relationships Communicating effectively ,Designing and making ,Devising and planning investigations Manipulating materials and equipment's effectively & Measuring and calculating
26	American Association for the Advancement of Science (AAAS) (1984)	Basic scientific process skills & Complementary scientific process skills:	observation, classification, data recording, measurement, using space/time relationships, using numbers, inference, and prediction, Changing and controlling variables, interpreting data, and hypothesizing, operational definitions, using data and formulating models, and experimenting. (Padilla et.al.)
27	Improving Quality of Science Teacher Training in European Cooperation Constructivist Approach (IQST): 2006	A basic process skill & A higher-level process skill	Observation, classification, communication, measurement, prediction and inference. identification, manipulation, interpretation, operational definition, formulation of models, experimentation, construction of hypotheses and drawing conclusions

From above table it is cleared that in the first phase of historical development of Science concept it only bridged with or linked with problem faced by the human being. At that time science was turn around with only concept like Scientific investigation & scientific inquiry which generally starts from problem identification & ends with the skill conclusions.

Science Process Skills as a Part of Process of thinking and Scientific Inquiry:

In the early stage of 19th century Dewey (1910), Dressel et.al (1949) & Burmster(1950) mentioned some science process skills under the term like process of thinking, elements of scientific thinking & abilities of scientific thinking with wide application which gives reliable knowledge about the natural world.

In 1910 Dewey formulated steps in the process of thinking & in 1937 Karl Pearson's identified steps of scientific inquiry in which some of the Science Processes are included as Observation, identification of problem, hypothesis formulation, testing, and hypothesis accepted or rejected. In 1944 National Association prepared a liberal approach to the sciences for pre-college program.

In the early 1950's Burmester developed a test focusing on inductive aspects of scientific thinking with separate abilities like Recognize problem, Understand experimental methods, organize, interpret Data, evaluate conclusions and make generalizations Oburn (1956) relate scientific investigation with problem solving includes sensing problem, collecting, organizing and interpreting evidence, selecting hypothesis and formulating conclusions.

Science Process Skills and Curriculum:

The recommendations of the Secondary Education Commission (1952-53) and the subsequent national seminar at Taradevi of the All India Council of Secondary Education had led to the introduction of general science at school level as a compulsory course. During the period 1957- 62, the major school science curricular trend was still general science.

The period 1962-67 was a watershed for the school science education policy. The Indian Parliamentary and Scientific Committee (IPSC) 1964 recommended the uniformity of courses and class structure as well as the upgrading of the content of science. The Education Commission (1964-66) criticized the general science approach and said that it was somewhat formless and without structure. It suggested the disciplinary approach. During the period 1967-72, efforts were mounted to implement the recommendations of the UNESCO Planning Mission (1964) and Education Commission (1964- 66). The National Policy on Education was declared in 1968 according to which emphasis was to be laid on the development of science and technology education.

Compulsory use of Science as a part of General Education up to class VII or VIII had been in practice before the introduction of uniform pattern of school education in 1975. During this period the subject was usually taught as general science in most of the states. However, at the secondary stage science was an optional subject which is offered either as combination of physical science & biology or as physics, chemistry and Biology.

The rapid changes in the Science Curriculum during the 1960's,focused on significant shift of emphasis during this period toward a science as a human activity with increasing curriculum emphasis on providing awareness or what scientists do.Bruner (1962) focused on acquisition of process of knowledge.

Thus, science curriculum in India has undergone several changes, both in approach and content, during the last forty years. At the primary stage, teaching of science as a single subject was first replaced by Environmental Studies (science) and subsequently by an integrated course on Environmental Studies. At the upper primary stage, the disciplinary approach was replaced first by an integrated approach to science as a single subject, and finally by an approach integrating science and technology

Klinckmann (1963) developed Biological Science Curriculum Study Test included one category as 'Ability to use skills involved in understanding specific problems' with 08 science process subcategories. Nedelsky (1965) classified the objectives of physical science course in college or high school in the form of learning abilities concerned with symbolic subject matter & real phenomenon.

The Secondary Science Curriculum Review (SSCR, 1987) identifies skills as being separate from processes. A skill is seen as a specific activity which a student can be trained to do. But a process is seen as a rational activity involving the application of a range of skills.

Some science educators (Simpson, 1987) raise strong arguments for a process-led science curriculum. They question the relevance of teaching of facts in the situation where information is generated in gigantic amount. Learning and education do not involve the passive handling and acquisition of information. Human beings are information processors, rather than information absorbers and active learning involves the processing of new information according to learner's previous experiences, needs, preconceived ideas, knowledge, and hypotheses. So in addition to the information skills, previous ideas, experiences, and hypotheses should present in the learners' cognitive structure.

Science Process Skills and Various Policies/ Committee's:

The Indian Parliament adopted the recommendations of the Education Commission as its National Policy on Education (NPE) in the year 1968. The highlight of the recommendations was that science and mathematics were, for the first time, made subjects for compulsory study for all pupils as part of general education during the first ten years of schooling. At the higher primary stage, emphasis should be on the acquisition of knowledge and the ability to think logically to draw conclusions and to make decisions at a higher level.

Ausubel (1968) argues that process skills, such as measuring, observing, classifying and predicting, are crucial for the development of a fruitful understanding of scientific concepts and propositions and for a meaningful use of scientific procedures for problem solving and for applying scientific understanding to one's own life.

A national curriculum framework was designed in 1975 suggested that, at the secondary stage, the science syllabus could be bifurcated under the titles Physical science, covering physics and chemistry, and the Life sciences, covering botany, zoology and human physiology

The 1986 policy reposed faith in the conviction of its predecessors that science and mathematics should continue as compulsory subjects in the first ten years of school education. Indeed, the teaching of science needed to be further perfected as virtually all aspects of growth and development in the modern era had their basis in scientific knowledge and as such, societies needed citizens literate in science and technology at various levels to ensure overall progress.

Subsequently, in 1969 National Assessment of Education Progress USA has included "Process" goals as one of the 4 major objectives of science programme.

The Scottish Education Department Consultative Committee (1969) on the Curriculum suggested the kinds of 'thinking' which pupil would develop by studying science.

Carin and Sund's (1970) in their model of interrelationship between Processes and Products explained that Scientific Processes includes Attitudes: intense curiosity, Humility, Skepticism, Determination, Open-mindness and Methods: Identifying Problems, Observing, Hypothesizing, Analyzing, inferring, extrapolating, synthesizing and evaluating

Wilson's mode1 (1974) provides two parallel sets of search processes-the empirical inquiry and the conceptual inquiry in which **empirical enquiry** includes observation, classification, inferring, predicting, quantifying, and simplification whereas **conceptual inquiry** includes attribute search, symbolic representation, conceptual testing, idealization and analysis for cause

UNESCO(1971) discussing process approach in science and mentioning processes like Observing, Classifying, Using numbers, Measuring, Using space time relationship, communicating, predicting, inferring, defining operationally, formulating hypothesis, interpreting data, controlling variables and experimenting.

Hurd (1971) described as processes which represents the intellectual means by which man organizes his observation, established data, and focused on problem.

Tennenbaum (1971) developed a test of science process based on observation, comparing, classifying, measuring, experimenting, inferring and predicting.

Klofer (1971) included Processes of Scientific Inquiry as a Observing, measuring, seeing a problem, ways to solve it, interpreting data, formulating generalizations ,building, testing as a category for objectives of Science Education.

Nay (1971) included process under the steps of scientific inquiry along with these changes Streven, Kothari, and Harry (1972) identified and added various process skills to the above list like communicating, abstraction making, extrapolating etc. Gagne (1977) considers these processes as intellectual skills.

From 1976 to 1980 various terminologies were used for the science processes as process abilities, elements of scientific thinking, scientific skills, and abilities of scientific process in terms of skills.

Andrew (1980) classified the abilities of scientific processes into six skills as Recognizing &defining problem, formulating hypothesis, collecting and interpreting data, evaluating hypothesis & formulating generalizations.

Paulose(1987) paying attention on initiation, manipulation& open endedness as a major components of scientific process skills. Again he mentions its 7 process categories & 17 process sub categories for students entering into the university.

According to Millar and Wynne (1988) SPS are general cognitive skills which man routinely employs throughout his life without any need for formal instruction.

Besides that Bhatt (1988) arranged the processes from Observation to Prediction in hierarchical pattern & identifies that processes are cumulative in nature.

UNESCO in 1992 summarizes the process skills in the form of indicators of primary school children are observing, Raising questions, Hypothesizing, predicting, finding patterns & relationships, Communicating effectively, Designing & making, Division & planning investigations, Manipulating materials & equipment's effectively & measuring and calculating.

According to National Research Council (NRC) standards, SPS is integrated into the broader abilities of scientific inquiry; therefore, the standards include the "process of science" and require that students combine processes and scientific knowledge to develop their understanding of science. One of the goals of these standards, students' use of "appropriate scientific processes and principles in making personal decisions," is an important cornerstone in science teaching (NRC, 1996, p. 13). National Curriculum Framework for School Education (2000) objectives of teaching science also underlines the importance of Science process skills.

American Association for the Advancement of Science (AAAS) classified scientific process skills as Basic scientific process skills :observation, classification, data recording, measurement, using space/time relationships, using numbers, inference, and prediction & Complementary scientific process skills: changing and controlling variables, interpreting data, and hypothesizing, operational definitions, using data and formulating models, and experimenting. (Padilla etal., 1984).

Improving Quality of Science Teacher Training in European Cooperation Constructivist Approach (IQST): 2006 distinguish science process skills into **A basic process skill** involves observation, classification, communication, measurement, prediction and inference (Teaching The Science Process Skills: TTSPS; Padilla, 1990; IQST, 2006) & **A higher-level process skill includes** identification, manipulation, interpretation, operational definition, formulation of models, experimentation, construction of hypotheses and drawing conclusions. (IQST, 2006).

Science processes are quite different from the popular notion of scientific method. Some science educators are against the notion of the existence of such a 'special method of science', in the sense that, if a particular method is followed, discoveries will be made. (Thier, 1973). According to them there is no one scientific method, but there are certain general principles which govern the work of all scientists. The often-mentioned scientific method is the manner in which they report their findings, and not the way they gain knowledge. But these science processes characterize the activities of scientists, the way to locate and gather information, explore, search, and discover the truths of nature.

A general discussion of the science processes as given by various experts, Committees and policies reveals that, the science process skills have a hierarchical order. Some basic skills are needed for the acquisition of higher order or integrated skills. SPS is integrated into the broader abilities of scientific inquiry and scientific method. One can infer an overlap of many skills in a specific phase of a problem solving task and identified skills as being separate from processes. Science process skills are named in literature as intellectual familiarity (A.A.A.S., 1993) and scientific searching skills (NRC, 2000).

A reasonable portion of the science curriculum should emphasize science process skills according to the National Science Teachers Association. In general, the research literature indicates that when science process skills are a specific planned outcome of a science program, those skills can be learned by students. Teachers need to select curricula which emphasize science process skills. In addition they need to capitalize on opportunities in the activities normally done in the classroom.

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