

Nature of Science as a Dimension of Scientific Literacy And Rationale for Inclusion of Nature of Science in School Science Curriculum

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Abstract

The goals of Science Education are themselves ever evolving and dynamic in nature and hence the science education community has preferred to use the term Scientific Literacy (SL) as an 'umbrella term' denoting the array of outcomes expected of science education. At the same time the review highlights the emergence of new aspects of science learning that has compelled the reconceptualization of the term and reconfiguration of the structure of the term to include certain dimensions that were neglected earlier. One such dimension is the 'Nature of Science' (NOS) that has emerged as a significant dimension of SL particularly since the last decade of the last century and that still continues as an important area of research for the science education research community. The paper also provides rationale for inclusion of this emerging dimension while framing the school science curriculum. The objectives of this paper are: 1) to present a brief historical overview of evolution of the concept of SL and subsequently to identify the main dimensions as reflected in the contemporary conceptualization of SL in the global scenario. 2) To present the conceptualization of SL as reflected in the National Curriculum Frameworks of India. 3) To provide rationale for inclusion of this emerging dimension of SL viz. 'NOS' while framing the school science curriculum. The methodology of the paper is through a review of the science education journals to develop the theme of SL. Following this, the conceptualization of SL as reflected in the NCFs of Indian origin using google search engine. Further, some more journals were looked up to provide rationale for inclusion of NOS in the School Science curriculum. The findings are: 1) The dimensions of SL identified at the global scenario are- a) Content knowledge b) Science Process Skills c) NOS d) Science-Technology-Society relationship. 2) SL in the Indian perspective is conceptualized in terms of Content knowledge and its application in various aspects of life, Science Process Skills, development of scientific attitude but it does not directly identify NOS as an aim of Science Education. So the last finding/conclusion of the paper is to provide some significant rationale for including NOS while framing the School Science Curriculum.

Keywords: NOS, Scientific Literacy, science curriculum, science education, school science.

Article History: Submitted: 26th May, 2021,
Published: 30th June, 2021.

Revised: 07th June, 2021,

Accepted: 26th June, 2021,

I. INTRODUCTION

Education is the key to success and the road to success is transcended through the 'curriculum'. The curriculum is a framework or skeleton on which all the learning experience of schooling are designed that helps in attaining the goals of education. The principle holds equally well in the context of science education. The goals of education and for that matter that of science education dictates the curriculum of science in the schools. The goals are themselves ever evolving and dynamic in nature that has both socio-cultural, disciplinary and psychological determinants and hence there is a continuous need to revisit the issue of goals in a regular and comprehensive way. The goals of science education are varied and hence the science education community has preferred to use the term SL as an 'umbrella term' denoting the array of outcomes expected of science education. However, the term Scientific Literacy (SL) is itself flexible and dynamic that evolves with time and the other significant determinants of education. A review of literature do suggest the evolving nature of the term. At the same time the review highlights the emergence of new aspects of science learning that has compelled the reconceptualization of the term and reconfiguration of the structure of the term to include certain dimensions that were neglected earlier. One such dimension

is the Nature of Science (NOS) that has emerged as a significant dimension of SL particularly since the last decade of the last century and that still continues as an important area of research for the science education research community.

The purpose of this paper is to present a brief historical overview of evolution of the concept of SL and subsequently to identify NOS as a key attributes as reflected in the contemporary conceptualization of SL in the global scenario. Next the attributes of SL as reflected in the science curriculum frameworks in India is presented followed by a discussion on the differences that exist suggesting some measures that need to be adopted.

II. SL: HISTORICAL OVERVIEW

SL has a history of over six decades and the term formally emerged into the science education literature in the 1950s. Since the emergence of the term it has been discussed, researched and advocated as a goal of science education in different forms reflecting a plethora of conceptualization of the term. Provided that the literature is quite mature with respect to meaning and structure of the concept of SL. It is therefore justified to present a historical overview of the term.

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After about a decade of research related to SL, Pella et al. (1966) conducted a thorough review of literature between 1946 and 1964 and identified 6 dimensions of SL that were popularly included by researchers in their conceptualization of SL including NOS and society-science relationship, ethics of science, conceptual knowledge in science etc. Hurd and Gallagher (1969) further reiterated these dimensions in their own description of SL. Again, Evans (1970) interpreted SL in a different way and characterized it in terms of an attitude characteristic to science and an understanding of method of science. Dimensions such as science society relationships and NOS were implicitly involved in the concept of SL.

Showalter (1974) re-presented the model of SL including dimensions of NOS, science related values, science process skill besides the content knowledge in sciences. During 1980s a significant model of SL was developed by Hirsch (1981) that included 4 dimensions of SL viz. conceptual knowledge; scientific investigation; scientific thinking; and science-technology-society relationship. Similarly Shamos (1985) talked of interpreting the term SL in its true sense by incorporating NOS, Science technology Society and Scientific inquiry as the core components beside content knowledge of science.

A major breakthrough in socialization of SL was achieved when a multidimensional view of SL was conceptualized by American Association for the Advancement of Science (AAAS, 1989) while preparing benchmarks for science learning for its project to popularize science. AAAS conceptualized SL in terms of a knowledge dimension and a skill dimension covering a range of science aspects from content knowledge in science to knowledge related to interpretation of scientific claims in light of its epistemic bases and science process skills. The new development in conceptualization of SL was the spelling out of the behavioral representation of each dimension of SL.

Following in line with AAAS (1989), NRC (1996) presented a 6 dimensional view of SL, further analyzing the knowledge and skills dimensions to include the dimensions of content knowledge, scientific inquiry, NOS, interaction between science-technology and society, practical knowledge and scientific attitude.

Almost a decade ahead, with the increase in advocacy for popularization of science and spurt in advocacy for enhancing public understanding of science Norris and Phillip (2003) added dimensions considering the individual's ability to participate in socio-scientific issues and interpret scientific claims as significant science education goals embedded in the framework of citizenship education. Thus they emphasized that the ability to think critically of science is an important goal of science education and hence a part of any conceptualization of SL. They thus implicitly advocated the emphasis needed on epistemic aspect of science that mediates such interpretive and critical thinking abilities among individuals.

With the advent of 2000s the conceptualization of SL has matured and its structure has been consolidated as evident from a greater overlap among the author's with regard to the various dimensions of SL. National Science Education

Standards (2005) in the representation of SL reiterated the significant dimensions that have evolved with emphasis on relationship between science and other disciplines like mathematics, technology and human enterprise, science process skills, NOS and content knowledge of science. Miller (2007) presented a simpler version of his concept that included knowledge in science and knowledge about science as major dimension wherein the former included the content knowledge and process skills whereas the later included the epistemic characteristics of science.

Bybee, Powell & Trowbridge (2008) discussed on different ways in which SL has been interpreted depending upon the sophistication of abilities that one wish to achieve as a mark of being scientifically literate. Thus when SL is conceptualized in terms of abilities to superficially understand the concepts of science it is a mark of Nominal SL. When abilities are enhanced to include an understanding of the jargons in science it is called as Functional SL. Finally when the procedural skills of science are also included as goals, in the scenario, SL is qualified as Conceptual and Procedural SL.

However these are rather advocated for a multidimensional view of SL, wherein the goals of science education should include awareness of the history of science, NOS, what makes it different from other disciplines and the societal aspects of science.

Recently PISA (2015) summarized the different views of SL to develop a detailed conceptual structure for the term SL. It followed a different pattern and interpreted the term SL in terms of a set of attitude, knowledge and competencies needed to understand science, use them in their day to day life. The competencies summarized the scientific way of thinking and beliefs, knowledge dimensions summarize content knowledge, epistemic knowledge and procedural whereas context dimension summarized the ability to use science in different social and personal contexts.

In a nutshell, the authors have presented a wide range of interpretations for the term SL. Whereas many elaborated the multi-dimensional view of SL (Pella et. al; Shamos, 1995; Bybee et. al, 2008), several others presented an operational meaning of SL in terms of behaviours that are in conformity to a scientifically literate person (Evans 1970, Hurd and Gallagher, 1969)

III. SL: SUMMARY OF IMPORTANT DIMENSIONS

The historical overview presented in the foregoing section was used to summarize the significant dimensions of SL acknowledged by the Science Education community. A summary of this analysis is presented in Table 1 below:

A summary view of the table 1 clearly indicate towards the emergence of a four dimensional view of SL presented in Figure. The author's unanimously acknowledge SL to include content knowledge of science, science process skills, NOS and scientific-technology society relationship.

Table 1: Authors agreement over different dimensions of SL.

Author(s) (Year)	NOS	Science Process Skills (SPS)	Science-Technology-Society relationship	Knowledge of Science
Pella et al.(1968)	✓		✓	✓
Evans (1970)	✓		✓	✓
Showalter (1974)	✓	✓		✓
Shen (1975)			✓	✓
Hisch (1981)			✓	✓
Shamos (1985)	✓	✓	✓	✓
AAAS (1989)		✓		✓
National Research Council (1996)	✓	✓	✓	✓
Norris and Phillip (2003)	✓			✓
National Science Education Standards (2005)	✓	✓		✓
Miller (2007)	✓			✓
Twenty First Century Science(2008)			✓	✓
Bybee, Powell & Trowbridge (2008)	✓	✓	✓	✓
PISA (2015)	✓	✓	✓	✓

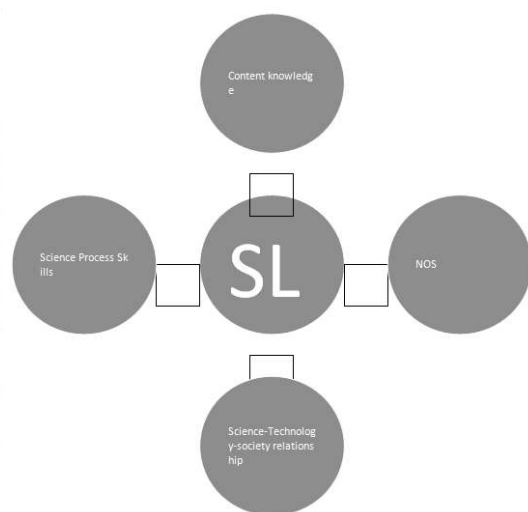


Fig 1: Dimensions of SL

IV. DESCRIPTION OF THE DIMENSIONS OF SL

Content knowledge in science- It refers to the body of knowledge made up of the theories, laws, principles, concepts, facts of science. In other words, we can refer it as the knowledge of scientific terminology, lexicon, jargon etc. This is a basic dimension of SL but it should be clear that for a person to be scientifically literate, he/she should have more than a super facial vocabulary of science, more of an understanding of these concepts.

Scientific process skill (SPS) - It refers to the set of skill required to process an unit of scientific endeavor. The skills

ranges from observation, to drawing of conclusions based on the observed evidence. Some other skills which falls in this category are classification, handling and manipulating instruments. NCF 1998 recommends teachers to design the lesson in such a way so as to encourage students to use SPS for arriving at inferences concerning scientific content knowledge.

NOS- NOS is a term lacking a general consensus over its meaning. NOS refers to the knowledge and understanding of students to know the true NOS like its tentativeness, dynamics, inter disciplinary aspect, limitations, epistemic beliefs of science etc. Some scholars also refer it as proper set, the process and product of science, being the subset. Some scholars have also referred it as 'knowledge of Science' (Rai and Bajpai, 2010, p. 11) whereas some refer it as 'knowledge about science.' (Miller, 1999).

V. SL, NOS AND SCIENCE CURRICULUM: INDIAN PERSPECTIVE

The different curriculum frameworks and education policy documents have accredited a significant place to science in the overall school curriculum. Although the term SL is not mentioned explicitly, the idea pertinent to SL can be abstracted from the recommendations and guidelines with respect to science education provided in these documents:-. With this assumption the following documents were reviewed to draw out significant statements on science teaching and learning. An iterative process was then used to analyze the statements to draw out a meaning for SL as is evident from the statements analyzed.

VI. FINDINGS

Finding is presented in the form of a summary of the statements identified from different documents in Table 2 below.

Table 2: Representation of dimensions in the NCFs

	NCF 2005	NCF 2000	NCF 1988	NCF 1975
Content Domain in Science (Product Aspect of Science)	✓	✓	✓	✓
Science Process Skills (Process Aspect of Science)	✓	✓	✓	X
Scientific Attitude	✓	✓	✓	✓
STS Issue**	✓	✓	✓	X
NOS	X* Not Explicitly mentioned. Different tenets of NOS are mentioned in an unorganized way	✓ * NOS is mentioned without any explication of the term of stand on what NOS.	X	X
Value System	✓	X	X	X

✓ : Explicit mention in document with proper explanation/

✓ *: Explicit mention without any explanation

X* : Not mentioned but included in unorganized way

X : Not mentioned or included in any way

STS** : Science-Technology-Society relationship

The analysis clearly indicated that the different curriculum frameworks since 1975 has emerged gradually to conceptualize SL in terms of content knowledge, science process skills, science technology relationships. The latest curriculum framework (NCF 2005) has laid great emphasis on values in science and science technology society relationship in its conceptualization of scientific literacy. NCF 2005 also speaks of different tenets of NOS particularly when it emphasizes the tentative and dynamic nature of scientific knowledge and the significance of creativity in science and technology. Nevertheless, the document fall short of presenting an clear idea on the model of NOS that is to be included in the curriculum and hence its position on NOS is half baked and far from being of any practical significance.

VII. CONCLUSION OF REPRESENTATION OF DIMENSIONS IN THE NCFs

In a nutshell it can be concluded that SL, in Indian perspective, is visualized largely in terms of science content knowledge and its application in different contexts, development of the basic science process skills and development of scientific attitude in the long run and in terms of values in science as incorporated in the latest curriculum framework. The document analysis clearly indicated that the epistemological aspect of science or NOS is still under represented in the overall framework of science curriculum. Provided that NOS has emerged as a significant dimension of SL, the under representation of NOS is a matter that cannot be overlooked.

VIII. RATIONALES FOR INCLUDING NOS IN SCHOOL SCIENCE CURRICULUM

NOS is a vital learning outcome that establishes the link between science content knowledge and the processes of science. Advocacy for NOS as an educational outcome has sound theoretical and practical bases. The significant bases that underpin logic for inclusion of NOS in science curriculum as a learning goal are summarized as below:

i. Epistemological Belief Rationale:

Epistemological beliefs relates to what one believes regarding the nature of knowledge and its development (Hofer and Pintrich, 1997) and such epistemological beliefs are held by even young adolescents (Schommer, 1993) including science epistemological beliefs (Griffith & Barman, 1991). It was further asserted that the sophistication of epistemological beliefs held by students determine the way they process and apply that knowledge in concrete situations (Hofer & Pintrich, 1997; Perry, 1970; Carey et al, 1989). As NOS represent science epistemological beliefs influences one's way of processing scientific knowledge and applying it in different contexts (Songer and Linn, 1991; Staver, 1998). It also influences one's orientation towards learning of science

(Songer and Linn, 1991; Lederman, 1992; Tsai, 1998), enhance students' interest in science (Mc.Comas, 1998) and assist them in reflecting on knowledge content (Larochelle and Desautels, 1991). Therefore inclusion of NOS in curriculum is well justified.

ii. Citizenship Rationale:

The second rationale emanates out of the reflections on science society relationship. The unprecedented dependency of society on scientific knowledge has created all new significance of science for society and its members. The ever increasing dominance of science in the life of modern society has further led to the emergence of several controversial social issues (socio scientific issues) with direct link to science demands active participation of the citizens in discussions and decision making processes. An understanding of the NOS is essential to perform the role of decision making. Millar and Osborn (1998), in their important document Beyond 2000, maintains that for a majority of students who are future citizens in different roles rather than future scientists, the core school science curriculum should be one that focuses on knowledge about science rather than knowledge in science where knowledge about science exclusively includes an understanding of NOS. Thus, science for citizenship aims at developing the citizens' capabilities to actively participate in debates and discussions related to such socio-scientific issues (AAS, 1989, Driver et al, 1996, Jenkins, 1999).

iii. Learning Rationale:

The learning perspective that dictates the current reforms in the science education embeds in the constructivist's paradigm on teaching and learning. Constructivism claims that the students build or construct their understanding of new ideas rather than acquiring it from outside in some ready-to-digest form. Learning, from an experience, is not a linear process and the prior experiences play a vital role in interpreting new situations (Miami, 2001). Constructivist philosophy is grounded in the Piaget's cognitive and developmental perspective, Vygotsky interactional and cultural perspectives and Dewey's educational philosophy. Dewey proposes that learning is active in nature and it takes place through experience. Experience involves the learner's active engagement and manipulation of some environmental stimuli and their Epistemological Belief system adapting his behavior accordingly. Similarly, Piaget emphasized that knowledge is essentially constructed and assimilation and accommodation are important processes in the construction of knowledge by the learner. Vygotsky supported Piaget's active learning and meaning construction. His social cognition theory emphasized that the cultural context including the family environment has a stimulating effect on the learners' process of knowledge construction. Thus, every individual is a constructor of his/her own knowledge. Similarly, the social environment and the cultural and family values of the individual all influence how they assign a meaning to any new information or idea. Provided that the cultural context provides the necessary tools for the individuals in the meaning making process, the norms and values of science as a culture need to be exhibited before the students. It has been claimed that the "Learners need to be given access not only to physical experiences but also to the

concepts and models of science [NOS]" (Driver, 1994, p. 6). It is through the knowledge about science or in other words the science epistemological beliefs reflected in the values and assumptions of science that an individual is enabled to use and apply scientific knowledge in different contexts (Driver, et., al., 1996). Such capacities can be enhanced only if the individual is able to comprehend the interrelationship between the different components of the structure of science and the bases on which they are accepted, their underlying assumptions and limitations. Similarly, the way in which students understand NOS influences their conceptual understanding of science content knowledge (Songer and Linn, 1991; Staver, 1998) and reflecting on knowledge content (Larochelle and Desautels, 1991). Such arguments favor an informed understanding of NOS on the ground that it helps individuals to develop a better understanding of scientific knowledge. It thus forms the learning argument in favor of developing informed understanding of NOS (Staver, 1998).

IX. CONCLUDING REFLECTIONS

The arguments presented in the foregoing discussion, justifies the advocacy for the inclusion of NOS within the gamut of science curriculum at the school level so that the students are initiated into the culture of science along with the basic assumptions, values and limitations of science. Further, NOS is considered as a definite set of cognitive learning outcomes rather than some affective outcome as a byproduct of science learning. (Driver, et. al., 1996). The curricular approach to NOS in vogue is however seen with skepticism owing to its inefficacy in achieving the goal of developing informed understanding of NOS.

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