Misconceptions in Science: A Theoretical Analysis

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Abstract: The knowledge of scientific conceptions is vital for any developing countries like India. While grasping scientific concepts Indian students unwillingly sum many Misconceptions and these misconceptions merely carry forward to the next higher classes together with the conceptions. This paper introduces some theoretical assumptions related to the misconceptions on the basis of thematic review of studies related to the misconceptions and alternative conceptions in context of India as well International. Total 43 studies have been reviewed for this study. This study defines the terms 'misconceptions' and 'alternative conceptions'. The study reviles that Indian studies related to the misconceptions are very less (viz. topics, level/class, textbook, curriculum, teacher related etc.). The study also reviles that some sources and nature of misconceptions.

Keywords*: Misconceptions, Science, Theoretical Analysis*.

Introduction: Advancement in science and technology are transforming the whole world at an amazing pace and our next generation is ought to be scientifically literate to cope up with the advancements both in their professional, personal and social lives. A minimum level of understanding of science and technology is no longer a matter of choice and rather has evolves as a necessity. Yet the understanding of science is difficult for many and often science is not taught in a way that enhances critical thinking among the students and rarely is they equipped with the tools to analyse and test a situation or problem (Ming & Fong, 1989). However, before these higher-level goals are achieved it is more important for the students, specifically the young learners to develop a proper conceptual understanding of variegated science phenomena, that inevitably constitute the fundamental structure for building higher mental edifices in science. Consequently, the science education research community have paid significant attention to the area of science concept development among the learners at an early age. Misconceptions in students' understanding of scientific concepts have been researched and are continuously an area of focus in science education literatures.

Misconceptions (MCs) are a common occurrence in the cognitive structure of the students irrespective of their grade or educational levels. Existence of MCs has been reported among the students at the primary level, secondary level, higher secondary level, and even at the graduate level. Furthermore, the existence of Misconceptions has also been reported among the teachers of science in several studies. Misconceptions are barriers in developing the appropriate understanding of science as well as it interferes in their future learning of science (National Academy of Sciences, 1997). It is therefore quite imperative for the science teachers that they are in a position to diagnose the MCs that exist among the students so that they can use corrective measures to overcome them or to appropriately design instruction that can help in development of the scientific concepts in its accepted form and structure.

Keeping in view the significance of the diagnosis of MCs for improved instructional design specifically so at the school level, a review of pertinent literature was conducted to analyze the various aspects of MCs that can serve as a reference for the researchers interested in exploration of this field of study and for the teachers to develop an understanding of the same as a professional.

Objectives:

The review of the literature was carried out with the following objectives in mind:

a. To review the definitions for misconceptions.

b. To identify the different concepts in science at school level in which MCs has been researched.

c. To present a review of the various sources of Misconceptions as mentioned in the literature.

d. To present a description of the nature of MC.

Method:

Review of literature was carried out from 2018-19 using Shodhganga, Google Scholar and Institutional access to journals as the medium for search. The literature searched included journal papers and thesis. Journal papers and theses (n = 43) that were in English language and published in reputed journals between 1990 and 2018 defined the limit of literature search. A total of 10 theoretical and 32 empirical papers and theses were included for review.

The review was carried out using a thematic approach where the various themes of interest are presented in the objectives of the review. A thematically presented review involves presenting and discussing the reviewed sources from literature in terms of "themes, theoretical concepts, and topics that are important to understanding or identifying from reviewing the key studies" (Sally, 2013).

Findings

The thematic review was carried out with the stated objectives in mind. The findings are narrated objective wise in this section.

Finding related to Objective 1

MCs has been a significant area of study for the science education research community since a long time. The Oxford dictionary explains misconception as a " view or opinion that is incorrect because based on faulty thinking or understanding" (Ajayi,2017). Etymologically the term misconception is constituted by attaching the prefix mis before the term concept. The term concept is derived from the Latin root word 'conceptum' that stands for "something conceived". The prefix *mis* is used to denote fault or inaccuracy or something wrong. Thus, misconception is understood as abstract ideas about any phenomenon that have error or inaccuracy.

Apart from the etymological meaning, the term misconception has been defined by the research community in different ways. Some of the major definitions of 'Misconception' are presented in Table 1 and definitions of 'Alternative Conceptions' are presented in Table 2 below.

S.No.	Author	Definitions
1.	Treagust, 1988	Students' "different ideas" that are "inaccurate" vis a vis the accepted ideas of scientific community" (p-159).
2.	Hynd & Guzzetti ,. 1993	Students' "beliefs that are held contrary to known evidence, and often derived from years of life experiences and observations"
3.	Goris & Dyrenfurth, 2010	The most common term misconception emphasizes the mistaken quality of students' ideas.
4.	Kaur, 2013	An idea about or an explanation for a phenomenon that is not accurately supported by accepted physical principles; a mistaken thought, idea or notion; a misunderstanding.
5.	Taber,2014	Learners often present ideas relating to science topics which are at odds with the target knowledge set out in the curriculum.
6.	Champagne and Klopfer, 1983	Naive theories and the distortions they engender in students' comprehension of instruction are among the principal causes of students' failure to achieve understanding in science.
7.	Moore et.al.,1997	Misconception is that they are part of a student's line of reasoning.
8.	Ajayi, 2017	A misconception is a conclusion that's wrong because it's based on faulty thinking or fact that is wrong.
9.	Ajayi, 2017	Student knowledge, however, can be erroneous, illogical or misinformed. These erroneous understandings are termed misconceptions

Table 1: Definitions of Misconceptions

S.No.	Author	Definitions
1.	Kyle et.al., 1989; McDermott, 1993;	Learners come to science lessons with a wide range of some already strongly held ideas, which may differ from the theories the educator may wish to develop. these ideas are referred to as alternative conceptions
2.	ABIMBOLA & BABA, 1996	We defined "alternative conception" as an idea which is neither clearly conflicting nor clearly compatible with scientific conceptions but which has its own value and is therefore not necessarily wrong.
3.	Goris & Dyrenfurth, 2010	Students' alternative conceptions are incommensurable with expert concepts in a manner parallel to scientific theories from different historical periods.

Table 2: Definitions of Alternative Conceptions

An analysis of the different definitions shows diversity in the way misconception is defined by the research community. Inductively it can be derived that almost all the definitions highlights misconception as sort of non- correspondence between the ideas and beliefs held by the learner and those widely accepted by the scientific community (Treagust,1988; Hynd & Guzzetti, 1993). The difference exist in form of some "mistaken quality" involving faulty reasoning in the schemas related to the particular concept (Moore et.al.,1997) and hence considered as "unfounded belief" (Mestre,1989) or naive theory (Champagne and Klopfer, 1983).

The review of literature further suggest that the term misconception is synonymously also referred to as alternative conception (Coll and Treagust,2001; Dikmenli and Cardak, 2004; Schussler, 2008), naïve theories (Cardak, 2009; Champagne and Klopfer, 1983), alternative frameworks (Blosser, 1987) and preconceptions (Cardak, 2009).

Finding for Objective 2:

2a. International Studies

Misconception in science has been reported to exist at all levels and over a wide range of science topics. The different areas and different level at which misconception has been studied and the reports of which could be located by the researcher in their review are summarized in table 3 below.

S.No.	Author	Year	Title	Topic	Branch of Science	Level/ Target Population
1.	Abak et.al.	2001	Effects. Of Bridging Analogies On Students' Misconceptions About Gravity And Inertia	Gravity And Inertia	Physics	Class 9th Students
2.	A. Coetzee & S.N. Imenda	2012	Alternative conceptions held by first year physics students at a South African university of technology concerning interference and diffraction of waves	concerning interference and diffraction of waves	Physics	Graduation Students
3	DAVID E. BROWN & JOHN CLEMENT	1989	Overcoming misconceptions via analogical reasoning: abstract transfer versus explanatory model construction	friction	physics	high school Students
4	*David Palmer,*	2001	Students' alternative conceptions and scientifically acceptable conceptions about gravity	gravity	Physics	Class 6th & Class 10th Students
5	Deniz Gurcay & Etna Gulbas	2015	Development of three-tier heat, temperature and internal energy diagnostic test	heat, temperature and internal energy	Physics	Class 11th Students
6.	Didem Kılıça*, Necdet Salamb	2009	Development of a two-tier diagnostic test concerning genetics concepts: the study of validity and reliability	genetics concepts	Biology	high schools Students
7.	Elaine Galvin, Audrey O' Grady	2012	To Determine and Overcome Biological Misconceptions Held by Students and Educators in the Irish Schooling System	Photosynthesise & Respiration	Biology	Secondary school students
8.	Erdal Taslidere	2016	Development and use of a three-tier diagnostic test to assess high school students' misconceptions about the photoelectric effect	photoelectric effect	Physics	Class 11th Students
9.	Ali Eryilmaz	2002	Effects of Conceptual Assignments and Conceptual Change Discussions on Students' Misconceptions and Achievement Regarding Force and Motion	Force and Motion	Physics	High school students
10.	ESRA OZAY KOSE et.al.	2009	Misconceptions and alternative concepts in biology textbooks: Photosynthesis and Respiration	Photosynthesis and Respiration	Biology	biology textbook Class 11th
11.	Gaitano Franke et.al.	2013	Investigation of Students' Alternative Conceptions of Terms and Processes of Gene Technology	Gene Technology	Biology	Class 10th Students
12.	George Stylos et.al.	2008	Misconceptions on classical mechanics by freshman university students: A case study in a Physics Department in Greece	classical mechanics	Physics	Graduation Students
13.	Zalkida Hadžibegović and	2013	Changing University Students' Alternative Conceptions of Optics by Active Learning	Optics	Physics	Class 11th Students

	Josip Sliško					
14.	Haluk Özmen	2007	Determination of students' alternative conceptions about chemical equilibrium: a review of research and the case of Turkey	chemical equilibrium	Chemistry	prospective student-teachers of First Year
15.	Schmidt et.al.	2003	Changing Ideas about the Periodic Table of Elements and Students'Alternative Concepts of Isotopes and Allotropes	Periodic Table	chemistry	High school students.
16	Abu-Hola	2004	Biological science misconceptions amongst teachers and primary students in Jordan: diagnosis and treatment	Endocrine system, Circulatory system, Digestive system etc.	Biology	Teachers and their Primary Students
17	Abayneh Lemma,	2012	Diagnosing The Diagnostics: Misconceptions Of Twelfth Grade Students On Selected Chemistry Concepts In Two Preparatory Schools In Eastern Ethiopia	oxidation number, valence, coordination number etc.	Chemistry	Class 12th Students
18.	Derek A. Muller and Manjula D. Sharma,	2007	Tackling misconceptions in introductory physics using multimedia presentations	quantum tunnelling, Newtonian mechanics	Physics	Graduation Students

Table 3: International Studies related to the Misconceptions in Science

Misconception has been reported in physical concepts like Force and Motion(Eryilmaz,2002); Gravity and Inertia (Abak et.al.,2001), chemical concepts like Oxidation and Reduction(Lemma,2012) as well as biological concepts like Endocrine system, Circulatory system, Digestive system, Respiratory system, Execration system, Inheritance (Human Inherited diseases and Inheritance and Environment), Plants (Parts, Growth, Photosynthesis, Respiration and Nutrition) and Hearing Mechanism (Hola,2004) among the school going students. The same has been reported among graduates in different disciplines of science such as interference and diffraction of waves (Coetzee & Imenda, 2012) and even among school teachers such as genes, photosynthesis and respiration, (Hola,2004).

2b. **National Studies**

Misconception studies located in the literature review pertinent to India context are summarized in Table 4 below:

S.No.	Author	Year	Title	Topic	Branch of Science	Level/ Target Population
1.	Mohapatra, A. K. & Bhadauria, M.	2009	An investigation of Indian secondary level students' alternative conceptions of water pollution	Water Polution	Chemistry	Secondary Students
2.	Chakraborty, A. & Mondal, B. C.	2012	Misconceptions in Chemistry at IXth Grade and their Remedial Measures	Atomic Structure and It's Properties	Chemisrty	Secondary Students
3.	Deshmukh, N.D. &Deshmuch, V.	2007	A Study Of Students' Misconceptions In Biology At The Secondary School Level	breathing and respiration, food, carbohydrates, vitamins	Biology	Secondary Students
4.	Deshmukh, N.D. &Deshmuch, V.	2011	TEXTBOOK: A SOURCE OF STUDENTS' MISCONCEPTIONS	respiratory system	Biology	Secondary Students
5.	Manmeet Baweja	Feb. 2017	A Study Of Errors And Misconceptions In Science In Relation To Scientific Attitude Among Secondary School Students.	Adaptations, habitat, food chain, functions of ecosystem' and biodiversity.	Biology	Secondary Students
6.	Manmeet Baweja	2017	A Study of Errors and misconceptions in relation to Gender among Secondary School Students	Adaptations, habitat, food chain, functions of ecosystem' and biodiversity.	Biology	Secondary Students
7.	Khandagale, Vidyanand Sambhaji & Chavan, Rajendra	2017	Identification of Misconceptions for Gravity, Motion and Inertia among Secondary School Students	*Gravity, Motion, Inertia.*	Physics	Class 9th students
8.	Sneha Jain	2014	Using 'History of Science' as a teaching tool to address students' misconceptions in science	'how plants gain mass'	Biology	Elementary Sudents
9.	P.K. Joshi	2013	Misconceptions in Science	Solar System And Atoms, Pressure, Temperature Etc.	Physics	Secondary Students
10.	Panse, S. & Kumar, A.	1994	Alternative Conceptions in Galilean Relativity: Frames of Reference	Frames of Reference	Physics	Undergraduate Students
11.	Sharma, N. & Kaur, T	2016	Effect Of Diagnostic Remedial Teaching Programme On Concept Understanding In Cell Biology	Cell Biology	Biology	Secondary Students
12	TESS-India project.	NA	Alternative conceptions: heat and temperature	heat and temperature	Physics	Elementary Students
13	Pathare, S & Pradhan, H. C.	2004	Students' Alternative Conceptions in Pressure, Heat and Temperature	Pressure, Heat and Temperature	Physics	Undergraduate Students
14	Pathare, S. & H. C. Pradhan	2010	Students' misconceptions about heat transfer mechanisms and elementary kinetic theory	heat transfer mechanisms and elementary kinetic theory	Physics	Undergraduate Students

Table 4: National Studies related to the Misconceptions in Science

The table 4 indicate that MCs have been diagnosed including those in Indian context are reflection and refraction (Joshi, 2013), Atomic structure and chemical bonding (Chakraborty, 2012), biological concepts like Adaptations, Habitat, Biosphere, Ecosystem, Food Chain and Food Web, Functions of Ecosystem, Biomass and Biodiversity (Baweja, 2008). The review in context of India revealed that the problem has been an important as well as popular theme among the science education workers. Studies related to MC was identified across the period of review in the context of India' even though the frequency of such studies lagged far behind the frequency observed for studies in developed countries.

The earliest work in the field dates back to 1994 (Panse & Kumar). Since then diagnosis of misconceptions has been persistently researched even though the density of such research is quite low relative to the utmost significance of such studies for pedagogical improvement. Further, the frequency of such studies (n =14) are even lesser and at the higher education level (n= 3) also.

Finding for Objective 3

The cognitive theories on learning suggest that learning is differentiation and organization of the cognitive structure (Piaget, 1964). Learning is an individual personal phenomenon that takes place within through the cognitive processes. The environmental variables including the teacher, textbooks etc. are external influences in the cognitive processing of information. Misconceptions arises whenever there is a shortcoming in the differentiation and organization of the cognitive structure when the organization of a particular concept in the cognitive structure in relation to its attributes and in relation to other conceptions are not proper leading to faulty reasoning by the students often leading to misconception in science.

The review of the identified papers and articles revealed that misconception researches have identified different sources for misconception in science through their empirical inquiry. Some of the significant misconceptions as revealed by the review of literature is summarized in Table 5 below. Each source of misconception is reported along with the source in literature that contributed in ascertaining the particular source of misconception:

S.No.	Source of Misconceptions	Description	Literature source for the category
1.	Religious/Non-scientific Beliefs	Certain religious beliefs are non scientific so its stand in direct contradiction to the scientific beliefs and serve as the source for misconception	Hola ,2004
2.	Peer Interaction	The interaction among the peer group may communicate some inaccuracies that directs to the development of wrong conceptual understanding	Wenning, 2008
3.	Text-books and Curriculum	Textbooks are the main learning resource for the learner. Erroneous representation of the concept in the text books or its faulty interpretation by the students can lead to misconceptions among the students that are long lasting.	(Deshmukh & Deshmukh, 2007; KOSE et.al.2009)
4.	Teachers	The teachers' knowledge is translated into students' knowledge in the classroom. Therefore misconceptions held by the teachers often get translated into students' misconceptions in the classroom.	(Deshmukh & Deshmukh, 2007)
5.	Multimedia:	Exposure to multimedia often exposes students to wrong interpretation of scientific concepts that persist even post instruction.	Muller & Sharma,2007
6.	Individual's Personal Experience	Constructivist perspective on learning assumes that the learner create his/ her own knowledge. When an individual perceives a concept of any phenomena through his/her improper observation, illogical thinking and wrong reasoning it eventually leads to misconception.	Hola ,2004
7.	Preconceived Notions:	The learners experience of science mediated by the teacher, textbook, family etc. constitute the past knowledge of the learner that in turn mediates there interaction with new information. Any erroneous preconceived notions can interfere in their interaction with new material and leads to further misconceptions in science.	Wenning, 2008

Table 5: Sources of Misconception

The summary presented in Table 5 reveal the multiple sources for misconceptions identified by the researchers ranging from religious beliefs to the teachers knowledge in the classroom that mediates the students cognitive processing of scientific concepts in an erroneous way and leading to development of faulty previous knowledge that hinders further learning by the students. The different sources are presented briefly in Figure 1 below.

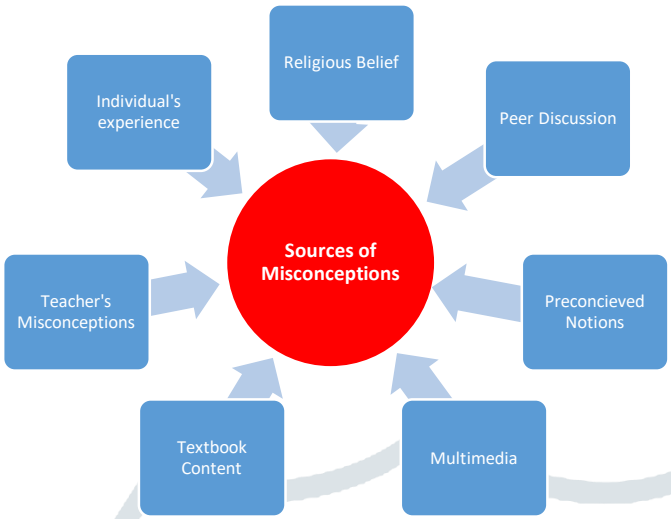

Figure 1: Representation of Sources of Misconceptions

Finding for Objective 4

Based on the review findings for objective 1 to 3, as well as different theoretical papers on science misconceptions, the nature of misconceptions are summarized as below:

- *Misconceptions can be diagnosed:* Misconceptions can be diagnosed empirically and this assumption is fundamental to all studies carried out with respect to misconception in science. Further, misconceptions can be remedially treated i.e.it can be transformed into the right concepts using several of the available strategies (Khandagale & Chavan, 2017; Sharma & Kaur, 2016).
- *Misconceptions have multiple sources of origin:* The sources for misconceptions are multifaceted. Textbooks, websites, journals, articles, magazines and even teachers can be a source of misconception. Ideally misconceptions are supposed to be remedied through instruction, however literature suggests that misconceptions can persist even post instruction (Deshmukh & Deshmukh, 2007; Kose et.al.2009).
- *Misconceptions have an interfering influence on new learning: M*isconceptions, once developed, mediates learning of new concepts. It is acknowledged that new learning is interpreted in association with the knowledge that constitutes the existing cognitive structure. Misconceptions once linked and organized in the structure, therefore influences interpretation of new learning among the learners. Such a situation leads to further mis-conceptions in the cognition of the learner (Moore et.al. 1997).
- *Misconceptions are embedded in erroneous reasoning:* Learning is a cognitive process of interpreting and organizing new learning material in the cognitive structure mediated by the logical thinking and reasoning. Misconceptions are revealed in the erroneous reasoning of the students related of particular concepts (Moore et.al. 1997).
- *Misconceptions can be remedially treated:* Formation of misconceptions is a universal phenomenon and it is common occurrence in science. However, since misconceptions are characterized by it's embedded in erroneous reasoning; the same can be identified and remedied (Chakraborty & Mondal, 2012; Sharma & Kaur, 2016). Thus treatment or correction of misconceptions to help the learners develop the concepts in its right form is possible.

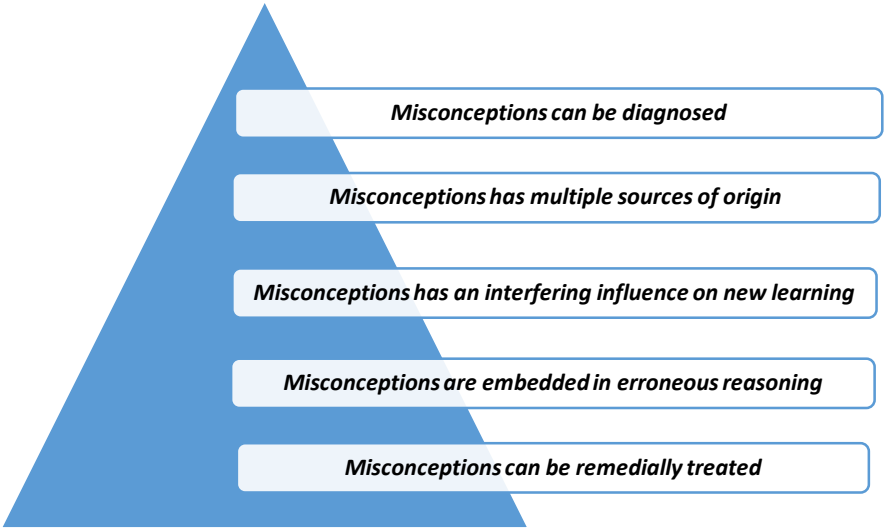

Figure 2: Representation of Nature of Misconceptions

Concluding Remarks

Science involves organized body of knowledge. Scientific knowledge is based on empirical evidences and at the same time it is characterized by rationality. Concepts and interrelationship among the concepts constitute the fundamental building block for the structure of scientific knowledge. Further, most of the scientific concepts are abstract in nature on the one hand and logically interrelated to constitute higher order knowledge on the other hand. Formation of misconceptions is therefore quite possible specifically among the young learners. However, misconceptions formed at any stage have a long-lasting impact on science learning among the students owing to its mediating role in future learning. Diagnosis and remediation of misconceptions is therefore a vital area of interest among science education research community that has persistently inquired into students' misconceptions in different topics in science. Student's misconception has been inquired into in the Indian context as well. However, the review of literature suggests that studies are intermittent with a sparse density even when the significance of such study is well established. The present review concludes that there is a need for frequent studies in the field of misconceptions.

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