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Understanding Students' common errors or misconceptions

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I. Introduction: The researches of students' conceptions have become the mainstream after David Ausubel (1968) brought up the idea of 'how the preconception influences the learning of scientific knowledge'. According to Novak (1988), "the role of conceptions in constructing human knowledge has been enhanced in science education." From the time of Piaget, educationalists have been intensely involved in how students view the concepts of science, mathematics, and, programming. Since four decades, a significant body of research has focused on students' understandings of scientific phenomena (Duit, 2006). The primary aim of science and mathematics education is to make students construct stable and meaningful organization of concepts in their frameworks. However, it should be stressed that students' prior knowledge is very important while constructing and organizing concepts.

Concepts, as abstract units of meaning, play a key role in the development and testing of theories. Concepts help to integrate apparently unrelated observations and phenomena into viable hypotheses and theories, the basic ingredients of science. According to classical theory, most concepts are structured mental representations that encode a set of necessary and sufficient condition for their application, if possible, in sensory or perceptual terms (Laurence & Margolis, 2000). Concepts are the most fundamental constructs in theories of mind.

II. Common errors or misconceptions: Various researches in education revealed that many students make common errors or hold many misconceptions or alternative conceptions during learning many concepts. In science, the word "error" means the "uncertainty" which accompanies every measurement. No measurement of any sort is complete without a consideration of this inherent error. Errors explored in physics experiments are of two types. First type of error is random errors caused by unknown and unpredictable changes and second type of error is systematic errors which are caused by measuring instruments being used incorrectly or problem

with the instrument itself. According to Solomon (1983), most student ideas are fragmented and not logically integrated. However, if students have a lack of articulation of their alternative conceptions, it might mean that either the conceptions are rather weak, or that the conceptions are there, but students are not yet fully aware and do not yet have the terminology to express them.

Misconceptions are very different from the mistakes students make. Mistakes are not consciously made. Misconceptions are. Mistakes are made by a few, misconceptions are made by many and, repeatedly. Students can figure out their mistakes by themselves because mistakes are usually due to carelessness. They cannot do the same for misconceptions. Misconceptions are committed because students think they are correct.

The dictionary meaning of 'error' is the state or condition of being wrong in conduct or judgement. Error also means belief or mental state that does not conform to objective reality; where what is correct is actually incorrect and is actually correct. A simple definition of error is, doing the wrong thing when meaning to do the right thing. The synonyms for error are: mistake, fallacy, misconception, inaccuracy, blunder, fault, oversight, flaw wrongly, erratum, literal, etc. In the technical area the meaning of error is a measure of the estimated difference between the observed or calculated value of a quantity and its true value. Barrass (1984), wrote of 'mistakes' or errors, 'misconceptions' or misleading ideas, and 'misunderstandings, or misinterpretations of facts. Misconceptions, defined as 'incorrect interpretations or misunderstandings of an idea, concept, or process, are often a large part of students' prior knowledge and experience. Misconceptions are obstacles in meaningful learning of concepts. Misconceptions are not only observed in today's children or students – even scientists and philosophers developed and lived with many misconceptions in the past (Barke et al, 2009). Misconceptions are a bi-product of children developing their own connections as they experience science or mathematics in school and in the world around them (Hansen, 2005).

Most of the researchers use term 'misconception' for 'common error'; in this article also author is using 'misconception' for students' common errors and their doubt. As Driver and Easley (1978), point out, “the term misconception has been generally used in studies where students are exposed to formal theories and have assimilated them wrongly. It's very clear that misconceptions are faulty ideas that are based on incorrect or incomplete information, limited experience, incorrect generalizations or misinterpretations and are consistent with the

student's intuitive understanding." Rosalind Driver and her colleagues in 1980 initiated studies on student misconceptions and have produced literature that is helpful to teachers and policy makers. Duit (2009) has recorded some 8400 studies across all areas of scientific learning.

According to the nature of learning problems, students misconceptions can be categorised as: i) informal ideas formed from everyday experiences which children bring into the classroom; ii) erroneous ideas developed during teaching due to lack of understanding; iii) wrong concepts propagated by teachers and textbooks. The Committee on Undergraduate Science Education (1997) categorized the students misconceptions as:

- Preconceived notions: forming an opinion prior to actual knowledge or experience.
- Non-scientific beliefs: from religious or mythical teachings.
- Conceptual misunderstandings: incomplete or over-simplified knowledge from previous science courses.
- Vernacular misconceptions: uncertainty about differences between the popular vs. the scientific use of words like work or theory.
- Factual misconceptions: falsities learned at an earlier time and retained.

School students come to the classroom with numerous misconceptions, that is, interpretation of various phenomenons, which differ, often radically from those accepted by the scientific community (Driver, 1989). Educators agree that prevalence of misconceptions among students not only presents a serious obstacle to learning in science and mathematics but also interfere with further learning (Novak, 1970). To promote effective and meaningful learning, there is a need to identify the causes of such students' common errors or misconceptions and find ways to rectify them or prevent them from occurring.

III. Identification of students' common errors or misconceptions: In order to correct the students' common errors or misconceptions, these common errors or misconceptions need to first be identified so that the students can replace them with new information. Several studies have shown that it can be difficult to convince a student to give up a long held misconception unless the new concepts are more valid, more powerful, more useful, or in some other way preferable to their existing concepts. One way to identify and correct misconceptions is to assess the students' prior knowledge, keeping in mind that giving the student the 'correct' information will not necessarily cause them to abandon their misconceptions and adopt this new information.

There are a range of methods available for the assessment of prior concepts. The difficulty, for a classroom teacher, lies in finding an accurate and reliable method which is not too time consuming. There are many methods for determining conceptual understanding and misconceptions such as, Open-ended questions, two-tier diagnostic test, concept mapping, prediction-observation explanation, interviews about instances and events, interviews about concepts, drawings, fortune lines, burr diagrams, and word association, questioning techniques, essays, two-tier multiple choice instruments, etc. Potential methods for identifying students' misconceptions are plays significant role. Interview is a widespread technique used to identify students' misconceptions because; interview is to tease out the students' meaningful understanding of a particular concept. The diagnostic instrument including true/false type questions, Concept Evaluation Statement, Proposition Generating Task, and writing essay also used to assess students' understanding of a particular topic. In addition, combinations of these methods have been utilized by many researchers to identify misconceptions. Nowadays, in the science, concept maps, V diagrams, clinical interviews, portfolios and conceptual diagnostic tests, etc are using as new assessment strategies to encourage meaningful learning and conceptual understanding (Deshmukh, 2015).

A search in the literature reveals that textbook, reference books, teachers, language, cultural beliefs and practices are some of the principal sources of high school students' misconceptions of many science concepts (Soyibo, 1993). Students hold misconceptions that are developed before and during their school years, and these misconceptions may be compounded by daily life experience, use of everyday language in a scientific context, compartmentalization of concepts, teaching strategies, and textbook. According to Storey (1992) the occurrence of misconceptions by students is textbook, which include many errors and incorrect information. In many textbook, many concepts are interrelated and they are keys to understanding other concepts. Therefore, not only lack of integration among topics but also in appropriate presentation of topics in textbook influence students' further understanding. Some of them rooted in everyday experiences. Many terms in science, mathematics and other subjects are used in an alternative way in daily life, for this reason, some misconceptions may arise from the use of words that mean one thing in everyday life and another in a scientific context such as heat, temperature, climate, fraction, area, chunking, food, respiration, and energy, etc.

IV. Examples of students' common errors or misconceptions: Research has long documented that people of all ages – elementary school children, college students, and adults hold misconceptions or made errors. Here below are examples of some common errors or misconceptions from science, mathematics, language, etc.

a. Day and Night: Baxter (1989) identified six ideas about day and night and showed that students tend to move through these ideas as they get older:

- The Sun goes behind hills.
- Clouds cover the Sun.
- The Moon covers the Sun.
- The Sun goes behind the Earth once a day.
- The Earth goes around the Sun once a day.
- The Earth spins on its axis once a day.
- The Sun moves across the sky.
- The Earth rotates in a clockwise manner.
- The Sun travels around the Earth.

b. Some of the common mistakes students do while solving problems in physics:

Applying conservation laws wrongly

Applying formulae in mechanics wrongly

Remembering only the important formulae and not the exact meaning of variables. Not knowing the limitations of the formulae.

c. Mixing units: The most common error made in solving physics problems involves mixing the units from one system with another system.

d. Getting refraction angles wrong: When you deal with refraction problems, make sure you get the angles right; they're measured with respect to a line perpendicular — called the *normal* — to the interface from one medium to the other. Many people incorrectly use the angle between the ray of light and the interface between the two mediums.

e. Plants: Photosynthesis and respiration is same. Elementary school children think of plants as nonliving things.

f. Gravity: Heavier objects fall faster than lighter objects. Many students learning about Newtonian motion often persist in their belief that heavier objects fall faster than light objects.

g. Multiplication of decimals:

Example: 0.3 X 0.24

Correct Answer = 0.072

Misconception answer: Multiply 3 x 24 and adjust two decimal points. 0.72.

a. Langauge: A correct understanding of language includes the knowledge that language can be used both literally and nonliterally. The misconception is that language is always used literally. Many elementary school children have difficulty understanding nonliteral or figurative uses of language, such as metaphor and verbal irony. The correct understanding of poems includes the notion that a poem need not rhyme. Misconceptions are that poems must rhyme.

V. Dealing with students' common errors or misconceptions: Avoiding students' misconceptions at school level is a real challenge for teachers, curriculum planners and developers. Fisher and Lipson (1986) suggested that errors in learning provide a window through which glimpses of mental functioning can be obtained. Errors are valuable and normal occurrences in the process of learning. A student can use his/her errors to develop a deeper understanding of a concept as long as the error can be recognized and appropriate, informative feedback can be obtained. A safe, non-threatening, and nonpunitive environment which encourages dialogue helps students to express their conceptions and to risk making errors. Pedagogical methods that systematically address common student errors produce significant gains in student learning.

Overcoming misconceptions is crucial for student learning. Researches on students' conceptual misunderstandings of natural phenomena shows that new concepts cannot be learned if alternative models that explain a phenomenon already exist in the learner's mind. Clement (1982), proposed two steps to modify students' preconceptions: i) students need to be encouraged to articulate their ideas and to use them to make predictions; and ii) students are encouraged to make explicit comparisons among their preconceptions, accepted scientific theories, and convincing empirical observations, to see which theory makes the most consistent and accurate predictions.

If misconceptions are not detected and corrected immediately; students' subsequent learning gets adversely affected. These deep-rooted misconceptions are major learning problems and continue to impact further learning process in schools. An important part of teaching is discovering how students make sense of course topics and using this knowledge to plan instruction that helps students recognize and change their misconceptions. Many researchers believe that students overcome misconceptions by recognizing and replacing them. Various instructional methods and remedial materials can be used to promote meaningful learning and to eliminate or prevent students' misconceptions. Research shows that the initial intuitive ideas become so deeply rooted in the student's mind that they continue to exert an unconscious control over mental behaviour even after the child has acquired formal notions of the idea that are solid and correct (e.g. Fischbein *et al*, 1985).

Students' conceptual frameworks develop from their experiences and change as they mature. However, frequently their intuitive understanding of the world around them does not agree with the scientific explanation. It is important in planning instruction to know how these misconceptions differ from the scientific explanation, and why students construct these ideas. According to Vygotsky (1978), concepts that are acquired from everyday experience are closely related to real phenomena, but lack coherence, whereas those acquired in a school environment are coherent but are isolated from real phenomena by the context in which they are acquired. The purpose of instruction is to help bring these two together, so that concepts acquired from everyday experience could be integrated into a coherent framework, and those acquired from school instruction become applicable in everyday situations.

Some 'constructivist' approaches recommend using students' existing ideas as an explicit starting point for developing new learning. Learners require extensive and deep, meaningful learning for the new, correct knowledge to come to mind. According to Perkins and Simmons' (1988) deep understanding involves four inter-locked levels of knowledge and teachers need to address all four: 1. Content: recalling facts, using vocabulary; 2. Problem Solving: strategies, self-regulation; 3. Epistemic: explaining rationales, providing evidence; and 4. Inquiry: critical thinking; extending and challenging domain-specific knowledge.

Rosalind Driver (1983) advocates a constructivist pedagogy which begins at the level of the individual learner, with student preconceptions. Students are encouraged to develop their models, step by step, alongside their experiences. The role of the teacher is to intervene, to pose questions, challenge the students' models, and guide them to a better understanding. Teachers are encouraged to look at the models embedded within student observations or questions, and become skilled at drawing these out. The teacher is thus a diagnostician, whose job it is to understand the learner's misconceptions and guide them to a superior understanding. These research findings provide researcher with knowledge base related to students' cognitive processes.

Discussion: As Charles Darwin quote suggested that, “False facts are highly injurious to the progress of science, for they often endure long; but false views, if supported by some evidence, do little harm, for everyone takes a salutary pleasure in proving their falseness; and when this is done, one path towards error is closed and the road to truth is often at the same time opened.” Studies related to the students' conceptions are being conducted seriously all over the world. Deshmukh (2007), conducted a study to find out misconceptions of students about biological concepts such as respiration, reproduction, circulation, photosynthesis, nutrition, excretion and classification of living organisms, observed that students had many misconceptions and displayed an anthropocentric view about these biological concepts. He found that teachers

had misconceptions about respiration, photosynthesis, nutrition, human blood circulation, reproduction, excretion and classification of living organisms. The textbooks analysis finding revealed that textbooks content had many errors in text and diagrams, illustration are not appropriate. This study also found that, textbooks and teachers were the sources of students' misconceptions. Researcher found that at the school level many complex and difficult concepts, such as photosynthesis, circulation, respiration, excretion, explained by providing correct notions and their fine elaboration of each concept and sub-concept, inter-relating the various concepts and sub-concepts and hands on activities approach was effective approach for remediation of students' misconceptions and helped students to correct concept formations (Deshmukh, 2012). Activity based or Inquiry based method may help in remediation and in bringing about conceptual change among students. Activities and questions have to plan in advance so teachers target their students' misconceptions. Ray & Beardsley (2008) explored the inquiry-based 5E (engage, explore, explain, extend, and evaluate) learning model and found that activities which incorporated different teaching styles engaged students with varied interests and were significant to overcome the students' misconceptions. The author, based on his experience in science education considered that confronting the misconceptions of the students through discussion, visual representations of concepts, and active involvement of students in learning through hand-on experiences enhances understanding. The proper sequencing and organization of the activities may help the students in overcoming the misconceptions and also learning the scientific concepts correctly. There should also be emphasis on history of science and importance & growth of science as a science to personal life of students for contextualizing biology education.

Conclusion: Considering the purpose of this teacher conference and from this article teacher will understand:

- what errors pupils will typically make
- how and why children make (these) errors
- how to help pupils to resolve such misconceptions.

As a teacher we all are aware the fact that our students are often making mistakes in classroom. The real question is why they make these mistakes? We must interpret these mistakes in terms of a theory - a learning theory. As teachers, all our interventions in the classroom are guided by some theory - be it conscious or subconscious - of how students learn certain concepts in classroom. Different teachers have different learning theories and addressing students'

mistakes in different ways. Teachers need to be aware of potential misconceptions and errors which may arise when students are learning specific concepts. As Olivier (1989), pointed out that, the knowledge does not simply arise from experience, it arises from the interaction between experience and our current knowledge structures. From a constructivist perspective misconceptions are crucially important to learning and teaching, because misconceptions form part of a student's conceptual structure that will interact with new concepts, and influence new learning, mostly in a negative way, because misconceptions generate errors. If teacher want to account for students' misconceptions, they must look at students' current schemas and how they interact with each other, with instruction and with experience. We have to understand the general principles of cognitive functioning from a constructivist perspective and we have to realise that, for the most part, students do not make mistakes because they are stupid - their mistakes are rational and meaningful efforts. As a teacher we have to find out the root/origin of students' common errors or misconceptions. Teacher need to discuss, communicate, reflect, and negotiate of meaning are essential features of a successful approach to deal with students common errors and misconceptions.

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