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Accessing Children's Ideas of the Natural World: an Exploration

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Abstract

The paper begins by examining different terms used to describe a variety of learners' ideas. The almost similar terms like concepts, conceptions; alternative conceptions, misconceptions are dwelt upon. The paper then goes on to describe the different approaches that cognitive researchers have adopted to understand the learners' thought processes in varying contexts. Most studies that have examined the alternative conceptions in different areas have attempted to categorise them. Some have tried to arrange these ideas in a hierarchical order based on their level of sophistication. Others have only juxtaposed these ideas into lateral categories, treating them as different ways of interpreting reality. Such attempts to impose order upon and look for similar patterns in the thinking processes of the students have then been discussed. Once the ideas have been accessed, the next step is to analyse them for any deviation from contemporary shared understanding and reflect upon the significance of these ideas in planning the course of further interactions with the learners. This has been attempted towards the end.

Introduction

By its very nature, science often poses comprehension linked challenges which could be attributed to factors such as lack of first-hand experiences, difficulty in comprehending the language, difficulty with mathematics and most significantly to difficulty in overcoming intuitive ideas. On the basis of our evolving understanding in the area of cognition and learning, it has come to be widely admitted among the educationists that learners' existing ideas in a particular domain

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need to be essentially taken into account and treated as starting points for planning future teaching-learning experiences for them. It is observed that 'idea' researches dominated the late 1970s, 1980s and 1990s science education research and brought to light many alternative beliefs that the learners may hold across various domains. The understandings of different concepts such as force, heat, light , energy, current etc., came to be widely documented across age groups and cultures. However, it is a challenge to unearth the subjects' underpinning ideas and world-views as their ways of looking at or reasoning about different aspects of the world do not get manifested in response to standard questions. Specially designed probes and innovative pathways are therefore needed that would provide a peep into the thought processes of the learners. Researchers in the field have had to devise different tools, such as the tiered multiple choice diagnostic test items, based on the need of the subject at hand. This paper presents a synopsis of the range of ways and means which the researchers have employed to get to the learners' basic understandings about the different aspects of the world.

Unpacking the 'Idea' Nomenclature

Various terms have been used for learners' ideas. In fact, usage of different terms in education literature often leads to confusion and a need to develop a theoretical framework based on shared language is now recognised.

Concepts and Conceptions

Though the terms 'concepts' and 'conceptions' sound and seem similar, there is a distinction between them that needs to be understood. Larson and Halldén (2010) explicitly distinguishing between 'concept' and 'conception ' say that 'concept' is used to describe a grouping of objects or behaviours on the basis of certain common features arrived at through research or wide spread use while 'conception' refers to the way an individual thinks about that grouping. So, while 'concept' is a category conception is the way that category is perceived and understood.

Alternative Conceptions, Misconceptions vs. Shared Conceptions

The origin of the term 'alternative conceptions' may be attributed to the term 'alternative frameworks' which was originally used by Driver (1981) to describe certain ideas that children bring to school which do not coincide with the scientific view. She says: "In some areas pupils hold beliefs which differ from the currently accepted view and from the intended learning outcomes of learning experiences. Such beliefs I shall call 'alternative frameworks'." (Driver, 1981, p.94). The term 'alternative conceptions' when initially used in the education literature referred primarily to pre-conceptions, naïve ideas or intuitive notions (i.e. conceptions held before receiving formal instruction) of children. However, gradually the scope of the term expanded to include all ideas that varied from the currently accepted scientific understandings. Traditionally, all ideas that were different from the scientific view were called the 'misconceptions' because they were considered to be incorrect and inaccurate conceptions that obstructed learning. Hawkins (1978) referred to these as 'false ideas' that 'block learning' and called them the 'critical barriers' but the contemporary understanding looks at these ideas differently. These ideas, instead of being considered as obstructions to be overcome are rather taken as starting points for future instruction. Further, many times these ideas may not be entirely incorrect but may incorporate certain correct features as well. Some of these ideas may also be pre-conceptions that have been resistant to formal instruction. The learners may also at times evolve some kind of 'hybrid knowledge' which incorporates ideas from classroom instruction as well as some beliefs students held prior to the instruction (Galili, 1996). Gilbert (1983) described alternative conceptions as 'ideas which differ significantly from the accepted scientific view at any time'. Dykstra et al.(1992) describe the following characteristics of 'alternative conceptions':

1. The 'mistaken' answers students give when confronted with a particular situation, e.g., "The sun goes around the earth."
2. The ideas about particular situations students have which lead them to make incorrect predictions.
3. The fundamental beliefs students have about how the world works, which they apply to a variety of different situations. These are beliefs in an explanatory sense about causality, e.g., 'motion implies force'.

They emphasise that 'alternative' in 'alternative conception' refers to the fact that students' knowledge about how the world works is different than that of the physicist. Gonzales-Espada (2003) noted that there could be many 'labels' for these variant ideas such as 'pre-conceptions', 'näive conceptions', 'näive theories', 'alternative frameworks' and 'misconceptions' but the term 'alternative conceptions' is preferred, because it values the idea construction process over the accuracy of conceptions. Also, the term allows space for the possibility that what is considered as an alternative conception today may become the shared conception in future and vice-versa. History of science throws up many such examples such as, in seventeenth century, the combustion process was thought to involve the absorption of a substance called 'phlogiston' and other observations were made to correspond with this fundamental idea which included assigning a negative weight to phlogiston. Then in the eighteenth century, Antoine-Laurent Lavoisier and Joseph Black came up with the caloric theory of heat according to which heat was considered a fluid called 'caloric'. It was only in early nineteenth century that heat came to be regarded as a form of energy. The usage of the term 'alternative conceptions', reinforces the dynamic and evolving nature of science.

Dykstra et al. (1992) also find the term 'misconceptions' inappropriate because according to them it ignores the rational basis of these explanations i.e., these conceptions are rationally based on students' experiences of the world. The term 'alternative conception' refers to the fact that students' knowledge about how the world works is different than that of the physicist but is based on reason. Smith, Di Sessa and Rochelle (1993) also criticised the misconceptions position as it only highlighted the erroneous aspects of the prior knowledge of the learners while ignoring their productive ideas which could form the basis of a more scientific understanding. They argue that 'misconceptions' need to be reconceived as faulty extensions of productive knowledge.

Pardhan and Bano (2001) who examined science teachers' alternate conceptions about direct current say that alternative ideas are those scientific ideas held by individuals which do not match expert scientific views. They acknowledge that these ideas have been given different names but add that the most common and appealing one to them is 'alternative conceptions' because these ideas are an individual's mental constructs, which make sense to the individual and work for the individual to make sense of new knowledge. It is personal knowledge that is at variance with public (accepted) knowledge. They point out that children as well as adults hold alternative conceptions and even teachers at all levels hold alternative conceptions. They found that not only many of teachers' alternative conceptions were similar to those of children but also that teachers show resistance to change just like children.

Siry et al. (2008) criticise the word 'misconception' because it had negative connotations vis-a-vis the learner. They elaborate that what teachers should do in soliciting prior knowledge of students is to respect the rudimentary 'misconceptions' they bring into scientific understanding and not view them as right or wrong but rather as an 'otherness' or alternative way of understanding a concept or phenomenon. Some researchers like Eijck (2010) do not distinguish between alternative, naive conceptions or misconceptions and talk of them as parallel terms. In physics education the intuitive knowledge of learners has been referred to by different terms such as facets, phenomenological primitives, coordination class, mental models and so on.

It is observed that usage of different terms often leads to confusion and there is a need to develop a theoretical framework based on shared language. The term 'alternative conceptions' may then be understood to refer to all 'ideas which differ significantly from the accepted scientific view' (Gilbert, 1983) of this day. Therefore, the term ‘alternative conceptions’ may include within its purview:

- Pre-conceptions that have survived formal instruction.
- ‘Hybrid conceptions resulting from the interplay between formal and pre-conceptions. These may not be entirely incorrect ideas but may incorporate some correct ideas as well.
- Limited conceptions.

The term ‘shared conceptions’ may refer to those ideas about a particular concept or subject, that are presently shared by the scientist community. The use of the term ‘shared conception’ instead of the ‘correct’ conception is depictive of the dynamic nature of science and allows scope for the possibility of revision of scientific knowledge which is how the disciplinary knowledge develops. The alternative/shared conception terminology is therefore more in consonance with our view of science. Rochelle (1992) who analysed the process by which two school children arrived at a ‘shared understanding’ of velocity and acceleration called this process ‘the convergent conceptual change’.

Accessing Children’s Ideas in Science

As discussed in the prior section, ‘alternative conceptions’ are the intuitive understandings of the world that differ significantly from the currently accepted scientific explanations. During the last four decades, the alternative ideas of the learners have been studied aceoss differenrt domains. Mechanics remained a prominent area of study as many of the commonsense notions of force and motion were found to clash with the Newtonian mechanics. Many tools that attempted to assess the learners’ understanding in specific areas were also devised. Optics because of its peculiar subject matter also emerged as a fertile area for study of alternative conceptions. In the last two decades, research efforts have also begun to be directed at designing instructional interventions taking the alternative conceptions as the spring board. Moreover, these efforts did not remain confined to school education but extended up to undergraduate and even teacher education level since it was realised that alternative conceptions are tenacious and resistant to change. The alternative conceptions though prevalent among children as well as adults may be difficult to identify and diagnose because learners may often respond correctly to standard questions while retaining their alternative ideas. To investigate such ideas, therefore suitable assessment tasks and focused probes need to be designed. The researchers in the field have employed a variety of methods to study these ideas. As noted from the review of studies on optics, researchers have adopted a variety of pathways to access subjects’ ideas such as *questionnaires* (e.g. Anderson and Karqvist,1983), *clinical interviews* (Goldberg and McDermott, 1987;

Guesne,1985), *class discussions* (Fetherstonhaugh and Treagust, 1992), *multiple choice diagnostic instruments* (Chen, Lin and Lin, 2002) and *openended questions* that may include predictive paper-pencil tasks where the subjects are required to predict what they are likely to observe under given situations (e.g. Ambrose et al.,1999 ; Atwood et. al., 2005). The process of construction of multiple choice diagnostic items has received much attention. The objective has been to dig out the underpinning ideas that lead to the elicitation of learners' overt responses and thereby understand their reasoning processes. For young learners the oral interactions or drawings, instead of paper-pencil work, are to be preferred.

Informal conversations or children's talk provides a helpful peep inside children's minds. *Children's drawings* often make up for articulation gaps and provide a helpful path to their conceptualisations of the world and could be used

- at the beginning of a teaching-learning session to learn what pre-conceptions children bring to the classroom,
- during the teaching-learning session to as a facilitative tool to help children sort out their own ideas, and
- at the end of teaching-learning session to see how their ideas have or have not progressed.

Shepardson and Britsch (2001) provide certain performance categories to assess a graphic product (drawing-cum-text). These are: sequence of activity, sense of scale and relationship between objects, level of detail, relationship between drawing and writing and carefulness. Minute examination and analysis of drawings could lead to cultivation of extremely useful insights.

Osborne (1980) put forward an 'Interview about Instances' (I.A.I.) approach to investigate students' understanding of a particular concept using an interview situation and a set of simple line drawings. It is posited that individual interview situation not only allows flexibility but also is helpful in evoking students' responses. Bell, Brook and Driver (1985) noted that if the alternative ideas of children are not addressed explicitly, the students maintain their alternative conceptions despite instruction. They present an overview of the approaches used by different researchers in recording the alternative conceptions of school students and report the following:

(a) Some researchers attempt to make inferences about students' conceptions based on patterns in their actions.
(b) In a few studies, students have been tested in groups through written responses or the use of diagnostic tests based on coded answer questions have been used.
(c) Many approaches have relied on student talk in various interview situations, the assumption being that, to varying degrees, oral language reflects cognition. The

use of manipulative material or other referents e.g., drawings also aid in the task of checking the interviewers' interpretations.

(d) Some researchers have followed up interview studies with surveys designed to indicate the prevalence of conceptions using larger or more representative samples.

Tsai and Chou (2002) also developed and tested a computer supported two-tier test system in which only one item per screen was presented. Every item was presented in two steps to prevent the influence on the first response by the information given in the second step in the sequence. However, when making the choice of the second tier, the first tier is kept on the screen. This may help students to select a reason that is consistent with their choice made in the first tier.

In a two-tier multiple choice test instrument, the first tier of each test item consists of a content question asking the students to predict the outcome of a situation and usually provides several distracters along with the correct answer. The second part of the item asks for a reason for the answer the student provided in the first part. The provided reasons from which the students choose include the correct answer and possible alternative conceptions identified in questionnaires and interview studies. Opportunity is also provided for students to give their own ideas in case none of the distracters fits their understanding. This consideration minimises the chance that students will just guess when they do not have any strongly held conception about the asked question.

Treagust (2006) presented a review of the development, in particular, of two-tier multiple-choice diagnostic instruments that have been reported in the science education research literature. It is noted that supporters of alternative approaches to assessment have not specifically elaborated on the value of specially created diagnostic tests but have recommended assessment items that require an explanation or defence of an answer, given the methods used. Three major aspects to development of these items that are highlighted are : (a) the content is defined by the identification of the propositional content knowledge statements, (b) information about students' conceptions is obtained from the extant of research literature, (c) development of the two-tier-multiple-choice diagnostic items. The first tier of each multiple choice item consists of a content question having usually two to four choices. The second tier of each item contains a set of usually four possible reasons for the answer given to the first part. The reasons consist of the designated scientifically accepted answer, together with identified students' conceptions and/or alternative conceptions. The alternative reasons are culled from the students' responses given to each open response question as well as from the information gathered from the interviews and the literature. When more than one alternative conception is given, these are included as separate alternative reason responses. Students' answers are considered to be consistent with the presently held view of the scientific community only if both, correct choice and correct reason are given.

Documenting and Learning from Learners' Ideas

Investigation of children's ideas in whichever way is deemed suitable, must however logically lead to their clear articulation by the investigators so that these can be analysed threadbare and appropriately addressed during the course of teaching-learning . These articulations will not come from the learners themselves but from the researchers who would have to creatively work out the thinking pattern of children on the basis of their interactions with the children. Reproduced below is a transcript of an interaction between a teacher and an 8-year-old.

Teacher (T) : light *kya hai?*
Student (S) : *matlab?*
T : *matlab agar kisi ko light ka nahin pata aur tumhe batana hai to tum kya kahoge?*
S : *batti*
T : (pointing to the tubelight): Yeh?
S : *Han par aap koun si light pooch rahi hain ? Waise to light roshni hoti hai.*
T : *Aur roshni kise kahoge?*
S : *Jo cheez chamakti hai.*
T : *Kaun si cheez?*
S : *Jaise jab torch jalate hain to uske aage jo cheez chamakti hai who roshni hoti hai:*

The above interaction gives some important clues about the way children think about light which is that

(a) children equate light with its source,
(b) children equate the effect (shine) with the source, and
(c) children think of light as matter.

Interestingly, these particular thoughts have been highlighted by many other studies as well. What is important to consider is that these cues to children's idea of light have been gauged from the above interaction and never at any point of time explicitly stated by children themselves. This should persuade all interested researchers to think up innovative ways to get to children's ways of thinking. Most studies that have examined the alternative conceptions in different areas have attempted to categorise them. The categories are sometimes hierarchical in order of sophistication. For instance, Selly (1996) presented a novel structure for displaying a phenomenographical hierarchy then constructed this hierarchy for children's ideas on light and vision. The structure proposed for displaying the hypothetical relationship between the conceptual models was called the Tower Block Analogy.

Level	**Criteria**
0	The most rudimentary level of understanding requires only an awareness of the conditions for sight: open eyes, unimpeded line of sight, and some kind of illumination.

1 Model A0. Recognition that there is a physical entity linking or travelling along a straight-line-path between object and eye, but retaining an ego-centric viewpoint.

2 Model A1. Recognition that there are two links, one involving the path of light from the source; but still ego-centric in the assumption that it is the eye, rather than the object which receives this illuminating ray.

3(a) Model A2. Recognition of the necessity for the conjunction of two straight line rays (one from the source and other from the eye) to meet at the object, if vision is to occur. This model fully satisfies the empirical evidence available to the learner.

3(b) At this same level there can be the growth of a very basic Reception model, for primary sources only. Light travels from the source, in a straight line until impeded (which would explain shadows), or until it reaches and enters an eye, giving a dazzling impression of the source.

4. Model B1. Acceptance of the theory of sight as the reception by the eye of light from the secondary source (which scatters or remits illumination).

Shipstone (1985) identified four conceptual models of electric current. These are termed as (a) unipolar model (current flows from the battery to the bulb–only one wire is considered active), (b) clashing currents model–current flows from both the terminals of the battery to the bulb, (c) current consumption model (the current is 'used up' by the bulb connected across the battery so that there is less current travelling back to the battery), and (d) the scientific model. The prevalence of the models is found to vary with different age groups so that the unipolar model is least prevalent among secondary students. The progression from models (a) to (d) is therefore also indicative of an increase in sophistication level of the model. However, there may not always be an evident sequence of sophistication in alternative conceptions and they could just come across as lateral and loose conceptions of reality. An example would be that of alternative ideas related to force and motion such as, 'constant motion requires constant force' and 'if a body is not moving, there is no force acting on it'. Further, these that may not be mutually exclusive as children may simultaneously subscribe to more than one of these ideas.

Having documented children's ideas, it logically follows that these are systematically taken into account by teachers and addressed during the course of teaching-learning. Appropriate addressal would require a thorough analysis of each one of these ideas. Analysis demands an in-depth reflection and contemplation on the factors that may have led to the formation of these ideas in the first place. The factors could be multifarious such as the subjective interpretation of everyday experiences or those that have to do with the represented knowledge such as the imagery or the language used to describe these experiences by people, teachers or even at times the formal texts. For instance, the 'light rays' used in ray optics may be taken as actual depiction of reality thus resulting in students assigning a materialistic status to rays and therefore to light. Chi et. al. (1994) propound that there are three primary ontological categories into which the entities of the natural world can be clubbed viz., matter, processes and mental states. The language used to discuss these entities therefore has to be in tune with their ontological status. Use of ontologically inappropriate language by the teachers in classroom explanations (e.g. referring to an entity belonging to the 'process' category as 'matter') leads to reinforcement of intuitive notions and strengthens the alternative views. However, there is little effort by the academic systems at the college, university or even at teacher preparation level to help the learners appreciate these subtleties of represented knowledge. Teachers recognising and acquiring a conscious awareness of these nuances of science pedagogy and responding to them by allowing them to bear upon classroom teaching-learning would be the first step towards addressing the alternative conceptions of children.

Conclusion

It is a challenge to unearth children's ways of thinking about the world as these often operate at the sub-conscious level and therefore are not freely available to clear articulation. Innovative means therefore have to be employed to actually assess the nature of these ideas and lay them out for analysis and reflection and examine them for some patterns if any. Each conception has to be dealt with separately and addressed during the course of the teaching-learning process. The approach has to be conception specific as the considerations for addressing different alternative conceptions would differ. Sometimes though, addressing an underlying conception may also lead to the addressal of some related conceptions. Children's 'variant ideas' have to be looked upon not as cumbersome 'obstructions to be overcome' but as 'strategic points for anchoring future interactions'. It may be pointed out that the teachers are crucial links that mediate between 'formal knowledge' and children's ideas that are acquired informally. Helping teachers develop insights into the nature of children's knowledge and how it is acquired can encourage them to revisit several of their own understandings thereby leading to improved teaching-learning practices.

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