# Overcoming the Cognitive Dissonance in Science Education

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**Abstract:**

For the last couple of centuries, science and technology became an engine of global development. It has made the world increasingly techno-savvy. As a result, people need to acquire certain scientific and technological skills to earn a good livelihood. The market caters to this 'social need' by conducting different courses in science and technology through schools, colleges, universities and many recognised and unrecognised institutions. The successful persons come out with flying colours and get well paying jobs. Thus, science and technology education does answer the need of earning livelihood. However, the students continue to carry dichotomies, some times throughout life. This paper deals with few areas of science education that suffer from dissonance mainly because of misconceptions, that have origins in every day experience, patterns of human relationships, world of emotions, various arts, aesthetics and religious faiths. Such a situation forces a student to adopt a fragmented life- one a personal life and the other a

professional life. The paper also suggests ways to deal with the fragmented science education as well as life itself by stressing the need to redraw a holistic science curriculum.

**Introduction:**

A comparison of global situation in last few hundred years shows that unprecedented material development has taken place throughout the world mainly because of science. The list of developmental indicators is quite large. Suffice to sight few examples: increase in human lifespan because of medicines, coping with increased global population due to higher agricultural production, many fold rise in the literacy and shrinking the world because of fast transport and efficient communication. This is despite the large-scale human and material destruction due to wars with the weapons of high potency and despite the wasteful consumption due to alluring markets. Naturally, science and technology and science education has acquired tremendous importance. However, the purpose of science education cannot be only to produce the next generation of scientists. Today we face issues on a global scale that are fundamentally complex and technical in nature. Climate change, balance between energy resources and its consumption, food production, fall in forest covers, wars and their effects, are just a few of the examples. The resolution of such complex and technical issues demand wise decisions based upon basic scientific literacy and wisdom. Unfortunately, both the scientific literacy and wisdom necessary to take decisions in the interest of common people are not genetic in nature. Each generation of students has to internalise them through quality education.

Let us not forget that teaching and learning science is a human activity, embedded in and influenced by society and culture in which both teacher and student grow. As a result, the socio-cultural interactive processes shape how students learn and understand science. All cultures have well developed theories about how the physical world operates, even though incorrect in the eyes of science. As a result, both the teachers and students carry misconceptions to a varying degree. If both carry a particular misconception, the teacher in first place may not even realise it and so cannot attempt to remove it from the minds of students. On the other hand, if only the students carry it because of their cultural background it amounts to a barrier in understanding the correct concepts. As a result, it is most appropriate to put our science education under a scanner.

**A typical science class**

In a traditional science class in most of the schools, the teacher stands at the front of the class lecturing to a largely passive group of students. At most, s/he resorts to blackboard, and to asking few questions during the lecture. The school uses lectures as a means of transferring information from one teacher to many students in one go. However, it is a common but forgotten experience that the extent of information retention is very meagre, when one listens to a lecture (a live one or in the form of a film by a world-renowned expert scientist) giving new information. That is why students back home, rote-learn the topic and do the exercises given at the end of the chapter of the textbook. Later, they take the examinations based on those exercises. In rare cases, the teacher is in a position to resort to experiments or activities. Even in such rare cases, the experiments and other activities operate like passive extracurricular activities. They do not transform the process of science education. The language that serves as a medium of instruction is the main bull-work of science education. Since our examinations focus mainly on the students' retention and retrieval capacities, the education in general and science education in particular continue in the same old fashion. However, the education system makes only cosmetic changes through increase of content load, printing of new textbooks, periodicity of examinations, etc. This education system is not child-centric. Only the child-centric education system can seriously attempt to impart science literacy and wisdom to the next generation. (This is true for all subjects and not just science.) For this change to take place, teachers and the schools should ponder over few questions: “if teachers teach why students do not learn? What are their difficulties? If students cannot learn the way teachers teach, can teachers teach the way students can learn? etc.”

**The misconceptions of students**

A science teacher may tell students to keep their baggage of ideas outside before entering the schools, but it is next to impossible. Children are born and brought up in a religious culture and hence are acquainted with many ideas that science is going to deal with. Students also come across some fantasy leaden variants of the religious answers through literature as well. Students have experience of most of the elders adhering to these answers and so feel those to be correct ones. After few years, a teacher of science tells them that keep your knowledge outside like one keeps shoes outside a temple and come in the classroom. Students cannot do that trick. They come in the classroom with a bag full of preconceived concepts that confront with the possible

answer of science with many question marks attached to it. In short, students already have internalised many misconceptions from the surrounding culture. Research[1] has identified reasons behind students' confusions, misconceptions and difficulties in internalising science concepts. Let us see few of them:

1. Students' ideas do not always evolve as quickly as the rate of concept presentation in most textbooks and in many teacher-designed units of instruction.
2. Language used by teachers and textbooks may confuse some students.
3. There is often unexplored conflict between students' everyday experiences and the classroom or textbook presentation.
4. Immediate introductions of scientific definitions and formulas (many of which are abstract) are not necessarily convincing or meaningful to students. They are useful only when students understand the underlying concepts. Traditionally many students engage in activities after presentation and discussion about the concept. These activities tend to be verification rather than inquiry-based where students construct an understanding based on observations and evidence they gather.
5. The present education system often expects students to understand before they have a chance to adequately explore and convince themselves of what they listen in the classroom. Ideas are often imposed on students, rather than allowing them to have the opportunity to make sense of something by exploring and developing ideas/models over time. "Covering" the curriculum without devoting enough time for building true understanding is counterproductive.
6. Beliefs resulting from personal experience, intuition, and "common sense" lead students to form their own ideas and models, often well before formal instruction. These experiences and feelings seem to contradict what students read in their textbooks and/or what their teachers tell them. Even with instruction, it is often difficult for students to give up these ideas, or they may revert to them later even though it appears they may have "learned" the correct ideas in class.
7. It is only a teacher who is aware of students' initial ideas, is likely to change students' unscientific ideas. It is similar to a doctor diagnosing an illness. You would not prescribe a course of treatment without examining the symptoms first.

- Teachers and schools (even tests!) often erroneously assume that students understand a concept based on the words students use when describing something (e.g. evaporation).
- Scientific terminology is not a sufficient evidence of learning unless you can ensure that students use the terms with fully understanding their meaning.

8. Demonstrations used by teachers are often passive where students sit back and observe without manipulating materials or experiencing the phenomenon individually or in small groups.
9. Pictures, diagrams, and 2-dimensional models in textbooks and other instructional materials can be misleading, and result in misconceptions.
10. Some of the common analogies used to explain ideas could cause difficulty because the analogies are after all analogies and when stretched too far loose their function.
11. Everyday use of certain terms, often used in non-scientific contexts, contributes to students' confusion. Some words have many different connotations in the English language and the "scientific word" can easily be confused with a common use.
12. Some ideas are just too abstract and difficult for many students who are still at a concrete learning stage.
13. Memorisation of ideas can cause more difficulty, particularly for "academically good students".

Children have and continue to have ideas about how the natural world works. These ideas come from their experiences outside the schools. Learning science during schooling adds some more ideas. Research has shown that teaching is unlikely to be effective unless teachers and curriculum materials take into account learners' preconceptions [2]. Let us see a few such common misconceptions or alternative ideas of students ranging from age five up to age sixteen (and some times of teachers as well). Some of these examples do illustrate the reasons behind the misconceptions enlisted above:

1. Humans are not animals.

2. Classification is mutually exclusive rather than hierarchal (example- some students have difficulty accepting that an organism can be classified as both a bird and an animal).
3. Soil is the plant's food. People put food (fertilizer) in the soil for plants to eat.
4. Plants only give off oxygen.
5. Photosynthesis is a plant process and respiration is an animal process.
6. Living things contain cells (rather than they are made up of cells).
7. Air has no weight (mass).
8. When something is burned, it is used up and nothing remains.
9. When water evaporates, it splits up into atoms of hydrogen and oxygen.
10. The bubbles in a boiling liquid are bubbles of air.
11. Soft things melt more easily than hard things.
12. Mixing colours of light has the same results as mixing colours of paint.
13. Light travels to an object, "lights it up" (is a common expression), and stays there.
14. Constant motion requires a constant force- If you want to keep moving along a horizontal track, you have to keep pushing; otherwise, you will run out of force and just stop. This represents a failure to distinguish the role of friction as a separate force.
15. Objects fall because of two things acting separately- gravity and the weight of an object.
16. Dinosaurs and humans existed at the same time.
17. Rain falls from clouds when they collide and split open.
18. When water evaporates, it just disappears and ceases to exist.
19. Moon phases result from the shadow of the earth cast on the moon.
20. Sun and moon are most often drawn between one to four earth diameters away from earth.

**Fragmented culture of science education**

Add to this list of misconceptions the difficulties having origins in the culture of science that is different from the normal culture surrounding the students. One may say, and it is true, that the world looks so different after learning science. Let us consider few examples:

- One may give an example of learning the growth of a tree. After learning science, one knows that primarily air and water make the bulk of a tree mass-the trunk, roots, leaves, flowers and fruits. It is interesting to know that when the tree burns or decays, most of the mass goes back to air giving heat that it had received from the Sun. Only the small ash is the part that the tree had taken from earth. This definitely is a very inspiring view of a tree that throws an array of questions. Let us ponder over few such questions: what are the differences in the viewpoint of science and creative arts regarding say a tree? After internalising the viewpoint of science, can one appreciate a tree in a painting, poem, or a sculpture? Can a totem-worshiping person still worship the tree? Can one retain his/her cultural associations? Is it all right to sacrifice one's culture at the altar of science? Does learning science make people **more utilitarian**?

- An example of sexuality begs another set of questions. Each one confronts an issue of sexuality at some stage of life or the other. For science, sexual reproduction is what matters. That is why even a liberal school invites a doctor to talk on sex education with the students. The substitution of sexual reproduction for sexuality is a high level of reductionism. It keeps away the emotional world of both the growing boys and girls that constitute sexuality, miles away. Except the war connotations, science and technology rarely touch the student's emotional world. The student is curious to know the recipe of atomic bomb but is rarely curious about how a flower blooms or how bamboo plant "knows" which year to bloom in? Does **science deal only with the non-emotional world**? Should science deal only with non-emotional world? Does looking at the world through the eyes of science and through the eyes of art and aesthetics creates a dichotomy? Does such a dichotomy operate only at individual level or at social level also?

- The existing curriculum introduces heliocentric theory from class III onwards. They come to know that heliocentric theory replaced the geocentric theory of planetary movements. Some of students definitely remember the names of great scientists involved. However, they do not know the reasons behind such a replacement. They are not aware of the fact that geocentric model also can explain the occurrence of day-night, seasons,

and even eclipses. Not only that, the out dated geocentric theory does explain movements of planets on the background of stars, albeit with more cumbersomeness. Most of the students even up to graduation fail to grasp that both these theories are nothing but mathematical models. It is just that one model is more versatile and mathematically more elegant than the other is. The study of science with such an approach forces students to believe that the Sun is steady and planets are revolving around it, forgetting that it is a matter of frame of reference. Similar is the story of the information regarding the heliocentric theory. Students sight the names of Newton, Galileo, Kepler or Copernicus in the discourse on heliocentric theory in the classroom. However, the students fail to establish any correlation between the competing theories and bright sky of daytime or the beautiful sky of the night-time. The Sun, the moon and many stars are visible in the sky but the mute heavenly bodies do not tell the student which heavenly body revolves around which one and why. As a result, in the eyes of students any scientist and Lord Krishna or Jesus is on a same pedestal. **Does that make life fragmented**? One fragment owing its allegiance to science, study, examination, marks-grades, career, marriage-prospects etc. and the other fragment to the other worldviews. The other worldview, for example the snake called *Shesha supporting the earth* is left to exist in a state of neglect. Eventually, the student acquires skills and even explains the occurrence of eclipses. Naturally, s/he obtains good marks.

- Science education helps develop a strong notion that **science deals with material world only**. An example of Newton's first law of motion or the law of inertia is not out of place here. After thoroughly learning it, one fails to understand how come a stray dog lying idle for hours by the side of a road suddenly stretches itself and starts not only walking but running as well without any external force. On persistent coaxing about this puzzle, the student often comes up with an explanation that the law is applicable to non-living things only. The student is happy because s/he finds consistency in the answer with some vague statement that science deals with only material world. One can further confront him/her with an evidence of the effect on persons in a moving vehicle, when the driver for some reason applies breaks suddenly. Now the student is completely baffled. Prescribed textbook does not mention whether the Newton's laws of motion are applicable to living

beings, especially mammals including humans. Since the student has to prepare for examination, which does not ask such questions, s/he tends to evade such complexity and concentrates on application of the laws for sailing boats, cycles, aeroplanes and even rockets. S/he gets marks and is happy with a thought that one is competent enough to apply the laws. The stray dog and the rocket that crosses the gravity barrier of earth are in two different law-tight compartments.

The endless list of such examples points to the state of science education today. The science education offers fragmented worldview that deals only with the material world and does not care for emotional world of human beings. The approach seems to be brazenly utilitarian and fragmented.

None the less, students embrace it because they need to acquire knowledge of science and technology for getting a good job. That is what market demands. It is no wonder then that even the 'successful' students carry numerous dichotomies and misconceptions.

**The market of science education**

Market with its complex forces and ruthless laws regulates the social life. At this level, policies and politics guided by financial interests is at the centre. If selling of a commodity is profitable, its market occupies central stage. It is immaterial whether the product is irrational combinations of medicines, forest products, tobacco, liquor, narcotics, weapons, or viruses (be they in the form of computer programs or biological ones) and antidotes in the form of either anti virus software's or medicines. The market cannot afford to be sensitive to its own effects. It may bring untold miseries to human beings in some or the other corner and may offer comfortable living conditions and even prosperity to people in the other corner of the world. Most often, the market makes the people insensitive to the miseries of some toiling and exploited people. That is why it is supposed to be ruthless. However, keeping conscience in a separate compartment helps an individual prosper and society to sustain the market. Education is just one of the many commodities for the global market. A commodity, that can be sold and purchased, a commodity that has quality dependent upon the cost, a commodity that has use value for the purchaser, etc. An individual possessing this commodity can acquire skills of achieving comfortable living

standards. The effect of such commodification cannot be different just because the commodity is education; it is bound to be similar. Students learn to keep scientific theories in one mental compartment and the other theories (misconceptions from the scientific viewpoint) in another compartment. The business of science education cannot address this sort of a dissonance that leaves behind a huge amount of vacuum inviting non-science culture to occupy it. The result of market oriented science teaching and learning is that it stops being holistic. The black holes in the science learning traps students, if not totally gobbles all of them up. A conscious effort to delink science education from ill effects of market and to design holistic curriculum can rescue the situation.

**Holistic Approach**

The present education is not in a position to tackle the world-views arising from the diverse fields of arts, philosophy, religion, occultism, etc and science holistically. Not only that, the education system operates as if it has resigned from such a task.. Individuals have accepted this reality and "successfully" adjusted to it. Even the loose talks based on two basic arguments reflect the acceptance. The two basic arguments are as follows: 1. such dissonances do not matter as far as development of science is concerned and 2. the informal education takes care of dissonances, if at all present. Some times the two arguments have an overlap also. Thus, there is subtle justification of the status-quo of the science education. That goes in to the subconscious mind of many people and revamping the education system becomes next to impossible. Let us see some such arguments:

- Look at the example of Sir Isaac Newton. The discovery of the three basic laws of motion, the law of gravity, some important discoveries in optics and development of calculus go to his credit. Newton gave shape and provided the basic rules of the modern science of physics. However, Newton had one more enduring passion in his life – and that was God and studying the word of God. He believed in existence of 'philosopher's stone' to convert base metals in to gold, the world would end no earlier than A.D. 2060, Bible [3, 4.] The argument is that his belief in occult studies did not interfere in the way of his scientific enquiry and achievements.

- Even today, one finds scientists from the faculty of physics, observing the religious rituals of eclipses or scientists from biological sciences believing in the theory of "creation" or in rituals after death.
- On the other plane, nearly each one of us can sight some names of individuals who appreciate the creativity, skills and achievements in the world of sports, music, poetry, paintings, theatre, films or sculpture on one hand and also in the world of science, technology or mathematics without any interference.
- Such individuals also know that experiences from one creative world can arouse associations from other world. They can skilfully keep the destructive interferences at bay and make use of constructive interferences to enhance the richness of experience of one field. Their life thus becomes rich like the beautiful interference patterns of light or that on the still water when one drops two or more pebbles nearby. Switching over from one world of creative activity to the other is not at all problematic for such people.
- One is also aware of the fact that some people had acquired skills and creativity in some or the other field through informal education. In support of such an argument, one sights the examples of famous cartoonist R. K. Laxman, or that of many film actors who never had formal training in their respective creative fields. It is also true that numerous persons in small-scale trades have acquired trade skills without any formal training.

Yes, people do learn many things through informal training. However, that presumes conducive atmosphere and opportunity for informal learning. As far informally learning the skills of a trade is concerned, it rarely helps persons to acquire the theories behind the skills. Secondly, the case of high-level achievements is perhaps the exceptions proving the necessity of formal training. A careful scrutiny of such arguments and examples of people does show the lacunas in them. It is also true that formal training does not guaranty the creation of great minds on a large scale. However, a good quality science education can elevate average level of understanding of science, its application and a training to appreciate different worldviews and place them in proper perspectives. With a better quality of the formal training, the results can be spectacular. As far as science education at school level is concerned, following aspects can improve the quality:

- Study the students' worldview or misconceptions from the viewpoint of science. It has to be an ongoing project because the cultural environment shapes students' worldview and it changes from place to place and from time to time. Some of the origins are from the fields like arts, literature, philosophy, religions, etc.
- Impart such knowledge to teachers before they interact with students.
- Let us not forget that we the people do need fantasies. Encourage students to appreciate these worlds. Do not negate the inputs of such fields; rather help students make a right place for it in their minds. The enlightened teachers simultaneously can persuade the students to observe how science looks at those aspects of life.
- Eventually students should be mature enough to place fantasies from various sources and the theories of science in different compartments.
- They need not dither visiting different mental compartments and the associations they arouse depending upon mood. In short, science need not come in the way of enjoying emotional world of art, literature, theatre, films etc.
- The new curriculum at primary levels should not have subject matter divided along the lines of today's man-made disciplines.
- Thus, make the science education holistic by incorporating the contributions of views from other creative worlds of human activities. This is nothing short of designing a new curriculum.
- Let the new curriculum replace the lecture method of teaching by methods that base on activities like experiments, field trips, project work, model making, etc. Remember that Chinese proverb: "I heard, I forgot; I saw, I remembered; I did, I understood."
- At higher levels of education, the heritage of knowledge can slowly bifurcate in to various branches.
- However, at both the above levels the contents and treatments of individual subjects should be holistic in nature. Let the science education not impart a feeling to the students that science teaching is devoid of emotional world.

**Conclusion**

Though science, technology, and its application has seen lot of progress in last couple of centuries, education and science education in particular has not kept the pace with the

development. The most important reason behind this is that education has become just another commodity in the market. Market is oriented to pack it in an attractive package and sell it. In the process, one forgets that science education inculcates a particular worldview. The other fields like literature, music, theatre, films, paintings, philosophy, religion even occultism etc offer different world views. A student in a real world absorbs all the worldviews to differing degrees. However, despite the long years of education, most of the times, students worldview remain fragmented. The fragmented worldviews cause many misconceptions in the minds of students leading to difficulties in science education and/or strengthening the fragmented worldviews. Only the child-centric holistic approach to science education can tackle the problem of multiple worldviews and provide the perspective to appreciate, to critique and to apply them in proper context. The paper argues that such an approach to science education enriches many faculties of students.

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