# Language of Science and Teaching Learning of Science

## A Constructivism Oriented Interface Overview

B. K. Parida*

J. K. Mohapatra**

**Abstract**

*In view of the indifferent attitude of students, teachers as well as teacher educators associated with science education towards language and consequences thereof, the authors attempt to highlight various issues related to language of science and its practice in teaching learning situations. This is important because (i) language is an essential tool for knowledge acquisition in constructivist paradigm, and (ii) language deficiency acts as an impediment in the academic growth and career of an individual, apart from the fact that language is central to knowledge creation and dissemination.*

### Prologue

It is generally observed that in our schools, when teachers teach science, students answer questions in science, whether verbally or in writing, language is hardly accorded due importance. Apparently, there are explicit instructions from boards of school examinations to ignore/ overlook language related faults of students while evaluating science papers. Perhaps all this stems from the perception that science as a discipline is isolated from language as a discipline and teachers and students of science need not worry about the accuracy/propriety of the

* *Professor,* RIE, Bhubaneswar-751022

** *Professor (Retd.),* RIE, Bhubaneswar-751022

language they use to communicate their knowledge and ideas. Even researchers in science sometimes have this kind of notion. However, the truth is that language plays a very significant role in science in all its forms, for everyone associated with it.

The importance of language in science can be seen in the simple but profound statement ascribed to the great English lexicographer Samuel Johnson (1709-84): "Language is the dress of thought" (Weaver, 1987), when it is combined with the fact that science begins and flourishes with thought. It sounds trivial that scientific ideas are invariably expressed in language and they would fail to achieve their objectives if the language is inappropriate. On the other hand, developments in science have resulted in enrichment of language through coining of new terms or finding new connotations of existing words. The deep connection between science and language can be seen, for example, in Physics and Philosophy, an excellent book authored by Werner Heisenberg (1901-1976), the 1932 Physics Nobel Laureate.

The book (Heisenberg, 2000, pp. 113-128) gives a lucid account of the evolution of scientific language beginning with Aristotle (fourth century BC) to the emergence of the path-breaking concepts of relativity and quantum mechanics (twentieth century AD). According to Albert Einstein (1879-1955), celebrated as the greatest theoretical physicist of the twentieth century and the 1921 winner of Nobel Prize in Physics, the wealth of scientific concepts and scientific language created and nurtured by excellent minds of the world has a far-reaching influence on human thinking, going beyond the national boundaries. It is a foregone conclusion that the mental development of an individual and her way of forming concepts are dependent upon language to a great extent. (www.openculture.com/2013).

However, the connection between science and language does not seem to be recognised in teaching learning situations to the extent desired. In our schools, science teachers and language teachers are almost like isolated bodies with hardly any cognitive exchanges on pedagogical and language issues that affect multitudes of students. Further, in most in-service teacher education programmes on science, the participants want elaborate discussions on 'content-cum-pedagogy' of teaching science concepts without evincing interest in the role of language in teaching learning of science. Needless to say, content and pedagogy are both language dependent. The pre-service education programmes for science teachers are also deficient in the matter of language. Though language is a curricular subject in various courses such as the one-year B. Ed. (Science), the two-year B. Ed. (Science), and the

four-year integrated B. Sc. B. Ed., it is mostly taught in a general manner without adequate reference to scientific language. These scenarios have an undesirable ramification leading to the notion that language is not a serious matter in the teaching of science. Clearly, this does not bode well for teachers or students. In fact, science teachers need to be more careful than even the language teachers as the former have to handle language in its multiple forms, from everyday words to domain specific technical vocabulary.

It may be pointed out that language-mediated social interaction, as propounded by the Russian psychologist Lev Vygotsky (1896-1934), has been recognized as a basic tenet of constructivism (Liu and Matthews, 2005). In practical terms, in constructivist approach to teaching learning, language plays a role more significant than in the traditional teacher dominated transmissionist approach. Constructivism advocates pupil participation in classroom processes on a large scale using varied strategies such as cooperative learning, working in groups, analysing a situation and voicing opinion, sharing ideas through dialogue/ debate, preparing and presenting a report, carrying out cognitive negotiation, etc. which give a learner ample scope to construct concepts as well as language. Realising the same, the National Curriculum Framework–2005 (NCERT, 2005, p. 38), recommends a 'language-across-curriculum' approach, observing that all classes, whether science, mathematics, or social science, are *ipso facto* language classes. Besides its role in science and mathematics education, constructivism has been found to be useful in teaching learning of language, online as well as offline (Kaufman, 2004; Can, 2009).

Against the above backdrop, the present article attempts to give a broad perspective of language in teaching learning of science for the benefit of teacher educators, teachers, and students. The underlying motivation is to expose them to a variety of language-based tools, which they may use in the process of knowledge construction.

Now a disclaimer is in order: the language used in this article does not claim to be 'the right language'; it may not even be the 'most appropriate language'. This is because there is nothing like 'the right language', 'a right language', or even 'the most appropriate language'. Whereas there is plenty of variation in language form and usage in informal and formal social and academic settings, domain specific technical language has less maneuverability and needs to be understood and used with a bit of care, while keeping in mind the fact that in science, content-appropriate language is more important than 'beautiful' or 'ornamental' language.

## Objectives

In view of the importance of the language of science in and outside

the curriculum, this paper intends to sensitise teacher educators, teachers, and students to some relevant issues such as

- The journey of an individual from baby talk to scientific language with expanding scope and ownership. (#1, #2)
- The subtle differences between the spoken and written forms of language. (#3)
- Language filters and fillers. (#4)
- The negative consequences of improper language usage and language inadequacy. (#5, #6)
- The importance of English as the global language of science. (#7)
- The nitty-gritty of the language of science. (#8, #9)
- The common language-related mistakes committed by students while answering questions in science. (#10)
- The problem of ambiguity in the interpretation of science formulae and the sanctity of definitions. (#11, #12)
- Language of science as a probable source of alternative conceptions. (#13)
- Language of questioning. (#14)
- Language as a tool for negotiation. (#15)
- The jerk technology. (#16)
- Ways of using language of science to make teaching learning more interesting. (#17)
- Discovering one's own mistakes as a professional. (#18)

These points are presented below as themes in a sequence indicated by the numerals in parentheses in the above list.

## Themes

### 1. From baby talk to scientific vocabulary

A child's journey on the language path starts at infancy when she/he begins making sounds and forming words, the so-called baby talk. With the help of the language of the family, she/he quickly picks up the social language. Though both these languages may be the mother tongue of the child, she/he can learn any other language on her/his own if exposed to the same. To cite an example, a three-year-old child of an Odia speaking family residing in an urban locality in Odisha joins a nursery school having children from different linguistic groups. In no time, she/he picks up Hindi and starts speaking a hodgepodge of Odia and Hindi at home. This is mostly an informal language. When rigorous schooling starts, the language picks up a formal tone, resulting in what may be called academic language. The child is made to formally learn other languages besides the mother tongue as a curricular requirement. As the education progresses a child gains proficiency in common formal language. At the same time, she/he learns the languages specific to different domains of study such as science, social science, etc. Further on, depending upon the chosen area of specialisation, she/he uses a *lingua franca*, the technical language,

that may not be understood by a common person. When she/he joins work, she/he may have to adapt to a workplace language, which may have its own nuances. Needless to say, one does not have to give up one of these varieties of language to pick up another; language acquisition is a cumulative process going through linguistic evolution and cognitive negotiation. We may depict the journey from baby talk to scientific language as in Fig. 1. At some point of time, a pupil may find that her/his mother tongue is inadequate and she/he switches over to English, though the transition may not always be smooth or painless and may require quantum jumps. In a country like India with multiple languages and linguistic groups, anybody wanting to succeed in life needs to be proficient in English, which is often used as a social language as well as a professional language besides being an official language. Of course, if one wants, one can also adopt a multilingual stance, using one language at home, another at workplace, and so on.

In the context of science, we may paraphrase the above in the following way: (a) there is student's language of science, (b) there is societal language of science, (c) there is textbook language of science, (d) there is teacher's language of science, and (e) there is scientist's language of science. The teacher has to be trained to transport herself/himself from (d) to (e) and help the students to gradually move from (a) to (e).

We should not forget that besides spoken and written languages, we too learn from sketches, diagrams, graphs, pictures, photographs, videos, films, animations, comics, etc., which may therefore be considered as linguistic tools. These days it has become a common necessity to learn from computer and smartphone driven Internet and social platforms, which have their own *lingua franca* that we need to learn to be able to use them effectively.

Language learning is truly a never-ending process for an individual. Learning a new word, finding new meaning of a familiar word, unscrambling a word jumble, etc. are enriching experiences at any point of time, in any language. Language learning is a good mental exercise that challenges the brain. Research studies show that when old people try to learn a new language, whether they gain proficiency or not, their brain functioning actually improves with regenerated neural pathways thereby easing age related neurological

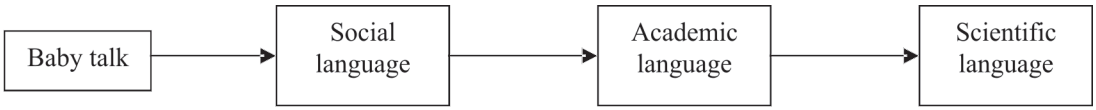


***Figure 1***

problems and decelerating natural age dependent cognitive decay. (Preville, 2015; Grierson, 2015).

Considering the three types of language users relevant to our discussion, namely students, teachers, and teacher educators, let us see how they stand relative to one another in the matter of language.

## 2. An inverted language pyramid

In view of the journey of an individual on the path of language leading to increased experience and expertise, we may think of two dimensions of language, namely 'language responsibility' and 'language ability', for students, teachers, as well as teacher educators. One ought to take the responsibility of acquiring and refining language, the responsibility growing with age and experience. Language ability of a person indicates to what extent she/he is able to achieve her/his objective using her/his language. In Fig. 2, we visualise a qualitative graphical presentation of these two dimensions in the form of an inverted pyramid, indicating how both these aspects are expected to grow from students to teachers to teacher educators. Note that in the beginning, even if students may have minimum language responsibility, their language ability is not zero and that is why the apex of the inverted pyramid is not a point but a line.

Let us recognise that the language ability of an individual has two dimensions: (a) usable vocabulary, which the individual normally uses, and (b) comprehensible vocabulary that the individual can understand. Clearly, (b) is broader than (a) and hence (a) is a subset of (b). In fact, (b) may constitute the linguistic Zone of Proximal Development (ZPD) of the individual. The concept of ZPD is due to Lev Vygotsky, referred to above, and indicates a range of tasks, just beyond the actual competence of a student, that the student can perform with external help or scaffolding. The teacher's responsibility is to make

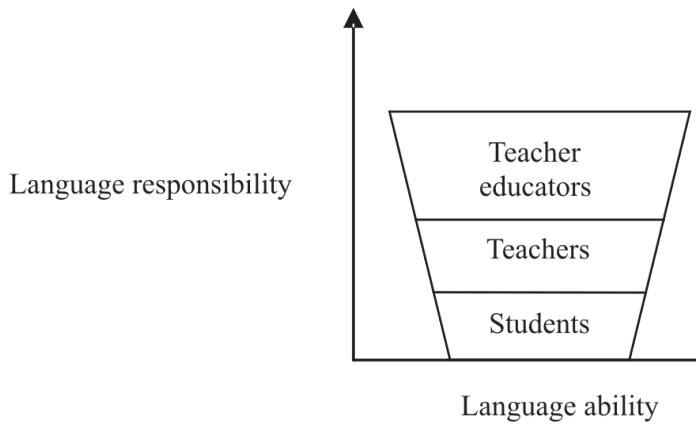


***Figure 2***

the student's domain (a) gradually richer thereby expanding her/his cognitive domain. This is one of the aims of constructivism-based teaching approaches. Constructivism also suggests the teacher to provide necessary scaffolding for the sake of ZPD.

Language skill of an individual involves cognitive functions such as listening, speaking, reading, and writing, usually in that order with increasing difficulty level. Though we are accustomed to use language in spoken and written forms as and when needed, there are subtle differences between the two, which may be worthwhile to keep in mind.

### 3. Spoken and written forms of language

Whereas the written form of a language is supposed to follow a set of stringent rules, its spoken form appears to enjoy more freedom, depending on the speaker. For example, different people may read aloud the same written line differently. Stress, accent, intonation, punctuation, pronunciation, etc. may differ from speaker to speaker in spite of the fact that there are standard rules governing them as can be seen in the books of grammar and dictionaries. These variations in spoken language are usually accepted. On the other hand, spelling of written words is standardised in a language and deviations can be easily located. Written form is more permanent than spoken form unless the latter is recorded for further use. In science lessons, pronunciation of technical terms and scientists' names (such as Coulomb, Gauss, Thomson, etc.) poses a problem, mostly owing to their unfamiliar origins. Even many everyday words are pronounced differently by different people; e.g. some use 'j' for'd' in 'education'.

Other features observed with teachers include mixing of singular nouns with plural verbs and *vice versa*, confusion between questions and statements/instructions, in spoken as well as written forms. Some teachers are known to exhibit some form of mannerism such as frequent repetitions of words like 'ok', 'this', etc. or, in other words, some teachers seem to have some 'pet' words which they like to use often, whether necessary or not. It is possible that this has become a habit with them and they do it without even thinking. Whatever be the reason, it is undesirable to repeat the same word in quick succession. With a bit of thought it is possible to use appropriate synonyms of a word instead of repeating it, or using other forms of the statement.

Sometimes comparison is made between the notes prepared by administrative personnel and the work teachers do on erasable boards in classrooms. It is said that the former is treated as a permanent official record and hence the concerned official cannot afford to make mistakes whereas the latter is temporary, to be found only in the notebooks of the students concerned

and therefore the teacher can escape with mistakes. However, the fact is that the mistakes of a teacher are likely to get into the cognitive space of the students thereby harming them in some form or other. The teachers thus need to be careful in their communications with the students, written or oral.

It is another general observation that students often do not ask questions or give answers properly. One important reason could be lack of skill related to spoken language. Learning a language in the form of words is not enough; it is important to know how to use the same. It is similar to the famous metaphor of 'learning the theory of swimming and not practicing it in the pool'. It goes without saying that words once spoken cannot be taken back and that they can make or mar a communication. Subsequent 'repair work' if any, may not ensure a complete recovery. Thus wrong/improper use of language, verbal as well as written, can be harmful in any situation. Teachers need to be careful about these matters and help students gather confidence and speak/debate/discuss in the class. They need not worry about their inability to use the language of science well to begin with; that would come with practice.

Let us now consider a couple of linguistic devices we often use.

## 4. Language filters/fillers

While listening to a speaker or reading a text, if we come across small mistakes/omissions, we often filter them out, or replace them, or fill in the gaps to get the meaning. This comes automatically to many of us. Some students do have this ability and use it in their learning process. Average students may lack the ability and hence rely only on what they 'actually' hear or read, which may affect their learning. The best option for a teacher in classroom is to utter/write each and every line fully with utmost care. This is important since students have a tendency to copy down teacher's board work entirely, including her/his mistakes, if any. It is in the best interest of students that they should also practice speaking/writing in full sentences in and outside the classroom. The teacher should dissuade students from using incomplete utterances and advise corrections, if any, on the spot, though she/he herself can make out the meaning using language fillers/filters. There is, of course, a possibility that improper language fillers may result in misunderstanding. Besides wrong fillers, even small glitches in language may lead to big mistakes.

## 5. Even a small slip may result in a big problem

An interesting fact about language is that even one word misspelt or misplaced can drastically change the meaning of a statement. A simple example: 'Write in correct sentences' may become 'Write incorrect sentences' if the gap between 'in'

and 'correct' is forgotten. We may take a few examples from science. The statement 'Clean water may be considered as an isotropic medium' will become 'Clean water may be considered as anisotropic medium', carrying exactly opposite meaning, if the gap between 'an' and 'isotropic' is forgotten or ignored. In a similar manner, 'in organic chemistry' may become 'inorganic chemistry' and 'a biotic sample' may become 'abiotic sample' where 'biotic' means 'living' and 'abiotic' means 'nonliving'. 'We have a paper on nuclear physics' becomes 'We have a paper on unclear physics' if the two letters 'n' and 'u' are inadvertently transposed.

Though such unwanted faults may appear to be extremely irritating/ embarrassing, these can very often be got rid of simply by a second reading of one's own written work. It is possible for everyone to make this a lifelong habit irrespective of the purpose of writing, a fact that needs to be drilled into the minds of students.

Having seen the necessity to be careful about the way we use our language, let us remind ourselves of its role in students' career.

## 6. Language deficiency can be detrimental to career

Lack of competency in language can actually act as an impediment in personal and professional growth of an individual. A case in point is a recent news item published in newspapers (Sambad, 2015a; The New Indian Express, 2015). It reports that many of the students passing out of the Government Engineering Schools and Polytechnics of Odisha are unable to clear even the preliminary written and oral examinations in campus selection processes owing to their inadequate knowledge in basic English even though they may have secured high grades in their subject papers. This is ascribed to their schooling in Odia and lack of training in basic English. Accordingly, the Employment and Technical Education and Training (ETET) Department of Odisha is planning a bridge course in English on the level of CBSE Classes IX and X for the benefit of such students. Now, a look at the national scenario: according to the national employability report of engineering graduates for 2014 prepared by Aspiring Minds, a leading employability solutions company of India, as many as 73.63 per cent of engineering graduates lack English speaking and comprehension skills (Nair, 2015; www.aspiringminds.in). Two important points emerge out of this: (a) language is the path that leads from an academic degree to a preferred vocation; (b) vernacular language alone may not enable one to tread the path in (a) successfully.

If we divide the secondary and lower level schools in India into vernacular and English medium schools, the number of the latter variety is appreciable, in the government as well as private sectors, irrespective of the quality of English used in these institutions. Beyond secondary level

the medium of instruction becomes English for almost all kinds of school. This is especially true in the domain of science as not enough text/reference books are written in the vernacular and it is difficult to find vernacular equivalents of the English forms of technical terms. This underscores the importance of English as a career building language irrespective of one's proficiency in other languages.

It leads to a related issue: how English came to be the language of science?

## 7. English as the language of science

Today, English is an international language. It flourished throughout the British Empire, which was the largest empire of the world from the late 16th to the early 20th century. A 2008 estimate showed that English was used as the first language by about 400 million people in 53 countries and as the second language by 1.4 billion more (Country Trends, 2008). Now, nearly two billion people use it, non-native speakers outnumbering native speakers 3 to 1. This is astounding when we realise the fact that English was the language of only three tribes just about 1500 years ago. (www.englishproject.co.uk/english-language-day/2013).

How prominent English has become in the world of science can be gauged from the fact that nearly 98 per cent of all scientific articles published are in English and 80 per cent of information stored on computers is in English ([92723] WEM_Fact_Science_Technology.jpg_low). But, in the early years, Latin was the language of science. With time, the importance of Latin decreased and by the middle of the 19th century, three primary languages emerged: French, English, and German. Then, subsequent to the two World Wars (1914-18 and 1939-45 respectively), German lost its place of prominence as a language of science, one important reason being the fact that Germany dismissed one-fifth of physics faculty and one-eighth of biology faculty for cultural and political reasons, who migrated to the US and England and started writing in English. Then, on account of the Cold War in the 1950s and 1960s, Russian became a major language of science besides English. With the decline of the Soviet Union in the 1970s, English gained over Russian. It may thus be said that the political events of the 20th century pushed English to the prominence it enjoys today. (www.popsci.com/article/science/fyi-how-did-english-get-to-be-international-language……).

Though English has overshadowed many other languages, it has borrowed significantly from them. English has a huge, powerful, and ever-expanding vocabulary catering to all branches of science and technology. People from all countries, irrespective of their own languages, are now keen to learn English. Globally, there is a growing tendency of publishing articles in English. A report (Weijen, 2012) shows that in advanced countries like

the Netherlands, Italy, and Russia, the ratio of English to local language journal articles published in the four-year bloc 2008-2011 stands at 43:1, 30:1, and 27:1 respectively. Another piece of study, referred to in the same report, shows that among the research articles published in English during 1996-2011 nearly 44.7 per cent were in the area of physical sciences comprising physics, engineering, and material science, whereas the shares of other areas were 23.4 per cent (life sciences), 19.5 per cent (health sciences), 10.7 per cent (social sciences, arts and humanities), and 1.7 per cent (multi-disciplinary and undefined). This indicates the popularity of English as the medium of publication in the relatively harder domain of Physical Sciences. Moreover, there is a host of free software available on the Internet such as LaTeX that helps in science publication.

In spite of the advantage of English as the language of publication, some researchers find it inconvenient. For example, a researcher in the area of Microbiology opines that whereas top journals require papers to be written in formal English, it could be a difficult task and wastage of time for researchers whose first language is not English (Raghava, 2012). Another researcher agrees to the above observation and says, "Any language is always a jail that prevents from communicating with those people using another one. English is a very very wide jail, and consequently you hardly can see its walls." (Tarancon, 2012). Tarancon suggests the use of an artificial language (similar to Esperanto), simple, syntax-free and regular, to be created by a convention of the scientific world. Perhaps the concept of such a language was first conceived by Orwell (Orwell, 1949) though in a different context.

Perhaps some dissatisfaction about the English language in general may be traced to the irregularity and non-uniqueness of spelling and pronunciation of even common terms in English. To quote one view: "English is so filled with ridiculous ways to spell words that it's really a wonder any of us can spell anything at all." (Harrison, 2015). One reason given for this is that English is a 'hodgepodge' of many other languages such as Latin, French, German, etc. each with their own peculiarities.

However, it is safe to say that India is well endowed in English, thanks to the long British rule and the indigenous linguistic multiplicity. English is recognised as the official language of the country in addition to Hindi. It is our window to the world and is favoured by many for writing of all kinds. Even, within the country, people from one region often use English as the means of communication with people from other parts. In fact, many native languages are getting enriched with English terms. See for example, Manivannan (2006, Internet). English speaking has also been influenced by the native languages, resulting

in what is popularly called 'Hinglish' (a mix of Hindi and English), etc. Though purists may not be happy with such developments, these have been accepted at large.

Having seen the importance of English as the language of science, it needs to be said that studying science subjects in English poses problems for those whose native language is not English. Researchers have tried to find the difficulties such learners face in comprehending and communicating scientific concepts, facts, and ideas in English. Helpful guide-books are written on such matters (see e.g. Allen and Widdowson, 1974; Longman Group Ltd., 1979; Singh, 2010). In the first book referred to above, the authors have used a number of topics from school level physical sciences (chemistry and physics) to illustrate language aspects such as reading and comprehension, grammar, paragraph writing, etc.

In this connection, let us take a look at the vocabulary of science, which has many interesting aspects.

## 8. The many hues of the language of science

The language of science is like a kaleidoscope. Its vocabulary comprises (i) common terms with ordinary meanings, (ii) common terms with specific meanings, (iii) terms peculiar to the branch of science, and (iv) accessories such as symbols, equations, diagrams, tables, graphs, etc. This is depicted in Fig. 3, with examples. Though all these components are important, dissemination of science in any form depends heavily on the first type whereas the relative amounts of the other components will depend on the characteristics of the target audience. The language of a science populariser may not be the same as that of a science teacher, which in turn may be different from that of a scientist writing for a research journal. A teacher ought to recognise that concepts of science cannot be appreciated without proper use of components (ii) and (iii). Therefore, any attempt to avoid/substitute

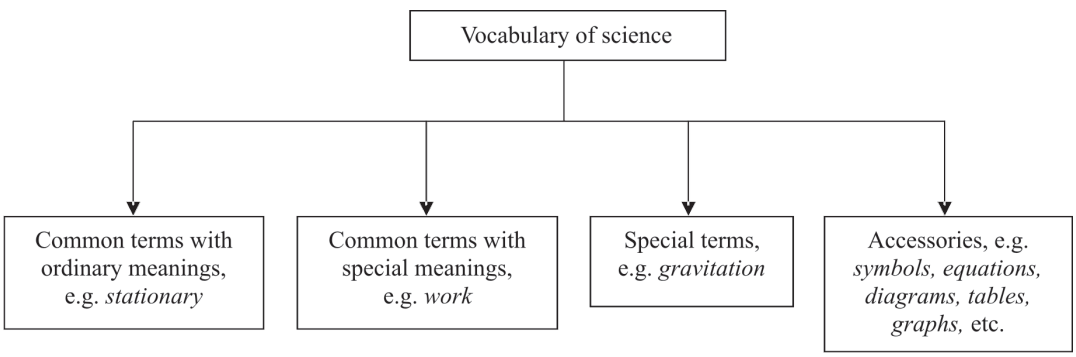


***Figure 3***

them in order to simplify science for students may actually be harmful and result in incorrect understanding or misconceptions.

The language of science usually follows certain conventions different from everyday language. Let us take a glance at them.

## 9. Special features of the language of science

Besides following the normal language rules such as grammar and syntax, the language of science stresses features such as 'precision', 'brevity', and 'objectivity' in expressions. It often condenses several ideas into simpler forms, e.g. "a body covers equal distances in equal time intervals" becomes "a body moves uniformly"; "the train is running with decreasing speed" becomes "the train is decelerating". In these two examples, the second statement uses technical terms whose definitions are explicit in the first statement. Even some names in science have become abbreviations of their original names. For example, 'oxy-muriatic acid' has become 'chlorine' and 'smoking spirit of salt' or 'muriatic acid gas' is called 'hydrogen chloride' (Sutton, 1998, p. 27).

There are international conventions on symbols and units of physical quantities, which need to be written following certain rules. These are usually described in textbooks on physics for higher secondary level (e.g. NCERT, 2006a, pp. 208-213) and are meant to be used by teachers as well as students to communicate science even when the language used is other than English. Though the units are formally introduced at senior secondary level, these are supposed to be used whenever needed, even in lower classes. Unfortunately, authors of textbooks are not always careful about these matters thereby misdirecting the teachers and students. A case in point is the secondary level science textbooks in Odia (e.g. BSE Odisha, 2013) published by Odisha Government. In these books, instead of using the English symbols for units as per the international convention, symbols/abbreviations in Odia script are coined and used. However, in the interest of students and their future, such non-standard practices should be replaced by the standard international practices right from their first formal entry to science. This is not at all difficult when we note that a universal set of symbols is used for chemical elements (such as H for hydrogen, O for oxygen, etc.) across languages, even in Odia textbooks without replacing them by Odia substitutes.

In this context, it may be noted that in science, certain words are used as a convention, in an adhoc manner. They may induce 'conceptual incongruity' in the cognitive space of the students. For example, the word negative is used while drawing the axes to plot a graph. If one of the axes represents time, then one has a negative time zone in the graph. Students fail to conceive the meaning of negative time. Similarly, in the

case of formation of image in mirrors one uses negative distances, whereas distance, being a scalar, is always positive.

Another dimension worth considering is the 'impersonal stance' of the language of science. In formal science writings as in research articles, textbooks, etc. personal subjective pronouns such as 'I', 'we', 'you', 'he', and 'she' are usually not used and passive voice is preferred over active voice. The students are advised to follow the same convention in their science related reports. However, history shows that at the birth of a scientific concept or the pronouncement of the results of a new study, scientists do take personal stand and carry out debates/ discussions/negotiations with peers on personal level. The personal tag is dropped when the ideas become a part of the accepted science. Clearly, the acceptance is a result of a social process involving scientists and mediated through language.

It is science in this person-neutral form that mostly finds place in textbooks. Thus, though the students get what may be termed the 'finished product' with or without the name of the scientist tagged onto it, they do not get to know the actual creative process underlying the same. As a result, their ability to appreciate 'doing science' gets affected and they may end up with a distorted view of science and scientists. This and other relevant aspects of language in science have been nicely put forth, with examples, by Clive Sutton in his article titled, 'New Perspectives on Language in Science' (Sutton, 1998). Sutton advises teachers to strike a balance between the product and the process, and formulate "a school language policy to recover the human voice and personal expression of thought" (ibid, p. 36). Sutton's advice is worth considering because of its intrinsic value, instead of leaving such important matters solely to the historians of science. If, for example, the teacher can place before the students those alternatives, which were debated and discarded in favour of the accepted scenario concerning a specific formulation or interpretation in science, it might be a great source of learning and inspiration for them.

In the early years of learning, the students may not able to exploit the special features of the language of science. Besides, they have a tendency to commit various kinds of mistake while writing answers to questions on science. We give below a set of common mistakes students are known to make in science in general and physics in particular. It may be useful for teacher educators and teachers to keep these in mind.

## 10. Common linguistic mistakes of science students

In 1996-97, an attempt was made at the Regional Institute of Education (NCERT), Bhubaneswar to discover a common pattern of errors committed by Class XII students while writing answers to physics questions. For

this purpose, 500 marked answer scripts pertaining to the 1995 Annual Examination of the Council of Higher Secondary Education, Odisha, were examined thoroughly by a group of subject experts. A list of the common errors/inadequacies thus identified (Parida, 1998) is reproduced here as we are sure it is still relevant today. It may be pointed out that no quantitative analysis of the findings has been done.

- Most students possess inadequate knowledge of English, their chosen medium of instruction.
- In many cases, answers are written in incomplete sentences.
- Sentences are often framed incorrectly, with punctuation marks ignored.
- General as well as scientific terms are spelt incorrectly.
- Symbols, particularly the Greek ones, are not properly written. It is often difficult to distinguish between α and a, γ and r, and so on.
- Explanation of symbols and terms appearing in various expressions is generally ignored.
- In many cases, physical quantities are presented without appropriate units.
- Diagrams are seldom drawn or labelled carefully. It is often difficult to distinguish between diagrammatic representations of a parallel plate condenser and a cell, resistance and inductance, etc.
- Equations are not written systematically. In equations involving vectors, for example, vector notation is not used uniformly throughout the equations.
- Students have a poor perception of graphs in general, including nature of the graph expected, procedure for plotting the graph, interpreting it and extracting information from it.

Another worrisome point related to language is students' handwriting, which sometimes becomes so illegible that nothing meaningful can be deciphered from it. Unfortunately, this may also happen to those whose understanding of science is rather good. A bad handwriting may not be good for one's academic growth. Flowery writing or calligraphy is not required in science; clear, legible, and unambiguous handwriting is good enough. It is good to note that recently the Government of India has issued guidelines to medical practitioners on how to write prescriptions such as writing names of medicines in capital letters to avoid possible ambiguities.

It is an irony that whereas with continuous development occurring in the domain of science there is a need to upgrade school level science curriculum, there seems to be a down swing in students' ability of language and arithmetic, as studies show from time to time (e.g. ASER, 2014). It may therefore be said that weakness in basic language skills such as reading, writing, spelling, and pronunciation makes science hard to learn for a large percentage of students. It is also

found that many do not understand typical action verbs such as analyse, assess, estimate, formulate, indicate, and interpret etc. which are used to form questions. Then there are subject specific terms to deal with.

As a means to ease these problems of students, the teacher needs to provide enough hand-holding kind of guidance, including drills on spelling, pronunciation, etc. The students ought to be encouraged to ask questions, give answers, take part in discussions using their own vocabulary, which may then be used to build their scientific vocabulary. Even distinctions between subscripts and superscripts, between capital letters and small letters, etc. have to be made a part of their academic work. Sometimes one may also have to deal with the dilemma of British English vs. American English. The students should be encouraged to develop a healthy reading habit and use dictionaries and glossaries almost as a habit. All this would definitely help the students construct their scientific knowledge well.

Let us now consider another dimension of the language of science, which may be a source of mistake, interpretation.

## 11. Language and interpretation–pitfalls in science

Between receiving an input and comprehending the same, there lies the vital step of interpretation. The same input may be understood variously by different recipients depending on their interpretations. Scientific concepts need to be expressed in a language that should be interpreted and understood unambiguously. However, it does not appear to be always so. We shall illustrate the point by referring to the definition of 'pressure', an elementary concept of science, and its interpretation by various authors, taking the following two cases.

Here, we shall examine how a mathematical formula is interpreted differently in the form of statements. In all these cases, the mathematical formula for pressure is the same:

$$\text{pressure} = \frac{\text{thrust}}{\text{area}} \qquad (1)$$

(i) In the highly popular and internationally acclaimed (since 1949) textbook, Sears and Zemansky's University Physics (Young and Freedman, 2004, p. 517), pressure at a point is defined as 'the normal force per unit area'. As the normal force is also called thrust, pressure becomes 'the thrust per unit area'. Thus, in this book, pressure definition as in Eq. (1) is correctly translated into statement.

(ii) On the other hand, in the NCERT textbook on science for Class IX (NCERT, 2006b, p. 139), the statement form of Eq. (1) reads, "The thrust on unit area is called pressure."

These examples show that the same mathematical formula is interpreted differently by different authors, some of which are not appropriate. In the instance (ii) above, the phrase 'thrust on unit area' may lead to the incorrect perception that pressure is the same thing as thrust. On the other hand, in (i) the phrase 'thrust per unit area' may be read as 'thrust divided by area', which corresponds to Eq. (1). To make the matter clearer, there is a prescription (www.physics.nist) according to which a quotient quantity ought to be written explicitly and so 'thrust per unit area' is improper and should be replaced by its proper form 'thrust divided by area'. Accordingly, 'thrust divided by area is pressure' and this is the unambiguous definition of pressure, in consonance with Eq. (1). On the other hand, thousands of teachers and lakhs of students are likely to be affected adversely by the interpretation as in (ii) over the years unless the matter is critically appraised and appreciated.

Another related dimension is definition, which plays a central role in science.

## 12. The sanctity of definition

Some teachers of science demand their students to reproduce verbatim the definitions given in their textbooks. They do not allow or encourage the students to paraphrase the definitions or restate them. This results in the notion that definitions are to be accepted in whichever form they are presented, without examining or analysing them. However, actually the language of a definition does change over time without changing its meaning and implication. Let us take, as an example, the famous Newton's first law of motion, which the students start learning from Class IX.

In the magnum opus, The Principia, published in 1687 by Newton (the creator of the laws of motion himself), the first law of motion is stated as: "Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon." (Newton, 2010, p. 19).

Another version of the same law, ascribed to The Principia, states: "Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it." (Cooper, 1969, p. 33).

In the Young and Freedman's textbook on physics, referred to above, the first law of motion is stated as: "A body acted on by no net force moves with constant velocity (which may be zero) and zero acceleration." (Young and Freedman, 2004, p. 124).

In the widely used NCERT Science Textbook for Class IX (NCERT, 2006b, p. 116), the same law reads: "An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state by an applied force."

The NCERT Physics Textbook for Class XI (NCERT 2006a, p. 91) on the other hand, defines the first law as: "If the net external force on a body is zero, its acceleration is zero. Acceleration can be non-zero only if there is a net external force on the body."

What is to be seen here is that the detailed language of the same law is different in different presentations though its inherent meaning is not changed. The moral of the story is that students should be encouraged and given freedom to re-express definitions in their own language without changing their meanings. This would help deeper appreciation of the underlying concepts and their interrelations and enable the students to hone their skills of language and analysis.

At the same time, it is important to realise that improper language may be symptomatic of improper comprehension of scientific concepts.

## 13. Language of science and alternative conceptions

Alternative conceptions (ALCONs in short) (see e.g., Mohapatra and Parida, 1995; http://apa.org/; http://www2.) are knowledge frameworks held by students in any subject before the subject is formally taught by the teacher. Gathered from a number of accessible sources by the knowledge holder, the ALCONs in science may be different from the established scientific knowledge and may be plain wrong. However, the ALCON holders consider them to be true or plausible in their respective cognitive frames and show a tendency to hold on to them unless they are discovered and modified or replaced in a convincing manner by the teacher, or are challenged by new inputs coming their way.

Needless to say, ALCONs act as stumbling blocks in teaching learning of science. Improper comprehension and inappropriate use of the language of science is one source of ALCONs. For example, many students think that speed and velocity, displacement and distance, force and pressure, weight and mass, are synonymous pairs of words, as is often used in everyday language. This, however, is totally wrong in the domain of science where each member of the above word pairs has its unambiguous definition. Glimpses of ALCONs may also be obtained by asking the students to define concepts in their own languages. For example, some students think that 'temperature is the degree of hotness or coldness of a body', whereas according to some others, 'temperature measures the amount of heat in a body'. In another example, when students are asked about the nature of their own images as they see in plane mirrors, most name the images as real though these are virtual by definition.

Clearly, such incongruities need to be unearthed and suitably dealt with by the teacher for fruitful learning of science. In constructivism, importance is accorded to the discovery of students' ALCONs and

how to address them by different means. It needs to be pointed out that even teachers possess ALCONs (see e.g., Mohapatra and Parida, 1995), which are likely to further jeopardise the teaching learning process. Therefore, teachers' ALCONs should also be explored, and this ought to be a responsibility of teacher educators. Even teachers who revisit their own thinking and storehouse of knowledge can also ease the problem of ALCONs to a great extent by recognising those themselves.

Questioning provides a common way of accessing ALCONs besides being an essential tool for gathering and strengthening knowledge. Let us take a look at its language.

## 14. Language of questioning

Questioning by teachers usually plays a great role in a science class, whether it is testing the previous knowledge, formative assessment, or summative assessment. Questioning thus occupies an appreciable fraction of the class time. Hence, it deserves consideration from the point of view of its language. Some teachers announce in the beginning of the class, "I'm going to ask you a few questions" or some variation thereof, upon hearing which most students feel threatened and try to 'hide' themselves away from the teacher's eyes. It is not uncommon for teachers to mix up questions and statements/ directions during a lesson.

Oral questions need to be short, to the point, and comprehensible to all students. Using technical terms in questioning may not always be wise as they are not likely to be understood by all; hence simpler but appropriate substitutes may be used. An example: "In what direction is light bent as it passes from air to water?" may be better received by a class than the one, "In what direction is light refracted as it passes from air to water?" (Yadav, 2000, p. 180). Here the technical term 'refracted' has been replaced by the simpler equivalent term 'bent'. Not only the teacher is supposed to ask questions properly in full and appropriate forms, the students should also be trained by the teacher to ask and answer questions using proper language.

Questioning may lead to situations where negotiation between the students and the teacher may become necessary to achieve a learning objective. This calls for a different type of language.

## 15. Language as a tool for negotiation

When a teacher communicates with the students in a classroom, explains a phenomenon, describes a demonstrative experiment, writes down a definition, dictates a formula, analyses the errors committed by students in their responses to a question, sets up a test paper, she uses a language which is a hybridised version of teacher's language of science and textbook language of science. This language is mostly a regimented and prescriptive one and is

imposed upon the students. However, in a constructivist approach, the knowledge constructors may resist such 'impositions' if they find these to be opposed to their perceptions.

Clearly, this calls for a strategy in which the teacher is viewed as a cognitive negotiator and the students are regarded as cognitive apprentices. This means cognitive negotiation has become a tool in the constructivist teaching learning process. (See e.g., Dykstra et al, 1992; http://woknowing.). If we go by the standard connotation of the term 'negotiation' that is, 'reaching agreement through conference', cognitive negotiation implies that the teacher and the students may have to reach understanding on certain learning points through negotiation. This becomes important and necessary in view of alternative conceptions or cognitive conflicts. It is an accepted truth that the language of negotiation is much different from a language of prescription because negotiation is based on the principle of cognitive accommodation whereas prescription is based on the principle of cognitive imposition. Thus, in the new scenario the language has to be more tactful, more persuasive, and should have the quality to open up new pathways, induce adjustments, help the students to accept desirable modifications in their cognitive structures, and realise the cognitive futility of their resistance to such modifications.

An example is in order. A child learns form early days that the sun rises in the east and sets in the west. This societal language of science may lead her/him to think that the earth is at rest and the sun is revolving around the earth. When the teacher, following the textbook language of science, states that the sun is at rest and the earth is revolving around the sun (a cognitive conflict for the child), it amounts to cognitive imposition and may not result in meaningful learning. Since this conceptual change is 'revolutionary' in nature, the teacher has to cognitively negotiate with the students by using suitable linguistic and other techniques.

Let us now look at another meaningful usage of language in classroom.

## 16. The 'jerk' technology

Due to the perceived nature of science as a 'cut and dried' discipline of study and the monotonous, unimaginative way of its transaction in classrooms, students often feel disinterested, inattentive and even sleepy. Moreover, children are known to have a short attention span, which is difficult to extend without changing the mode of transaction. The 'jerk technology' (JT) (Sansanwal, 2000) may prove to be a handy device in this connection. Using it the teacher can provide academic/mental 'jerks' to the students to revive their attention as and when needed. Here are some of the JT tools borrowed/adapted from Sansanwal. These are mostly applications of language.

**(i) Mirror image writing**

The teacher writes the mirror image of an important word on the board, which is a definite attention catcher.
Example:

**(ii) Word art**

This may include letters/words of disproportionate size or other fanciful writing, another way to grab attention.
Example:


**(iii) Small writing**

The teacher deliberately writes some important points in such small letters that the students are not able to read. This is likely to increase their alertness and generate a sort of anticipatory commotion in the class.

**(iv) Unusual sentence construction**

Example: Hari is *clearly unclear* about the laws of reflection.

**(v) Multiple words**

In order to put extra emphasis on what the teacher wants to say, she/he may use more than one word with the same meaning; combinations of words from different languages may also work fine.
Example: Gravity *provides/supplies/gives* the necessary centripetal force to a satellite.

**(vi) Misfit examples**

An inappropriate or misfit example or a non-example may be clubbed together with a right example to test the understanding and alertness of the students.
Example: Rectilinear motion occurs for a bus traveling on a straight path and the *second hand of a watch*.

**(vii) Teacher's known mistakes**

The teacher may deliberately commit a mistake in her/his board work and test whether the students are attentive and careful enough to catch it.
Example: $s = ut + (1/2)at$

In the above equation for the distance covered *(s)* by a body in time interval $t$ when it starts with a speed $u$ and accelerates at the rate $a$, the teacher has knowingly written $t$ in the second term on the right hand side in place of the correct symbol $t^2$.

To sum up, a teacher may use the above tricks to break the classroom monotony and make the class merrier and livelier. Clearly, these tricks do not involve new knowledge of science but use the standard language of science in interesting and creative ways.

Of course, there are other ways of bringing in a bit of entertainment and humour to science classes with the help of language.

## 17. Language of science can be humorous too

Besides the 'jerk technology' as discussed above, it is possible to make science teaching learning enjoyable in other ways too, using the concepts and principles of science. Let us discuss a couple of such devices. Somewhat unconventional, humorous and funny in nature, these tools can improve the thinking and creative ability of teachers and students alike and help in knowledge construction and consolidation. Needless to say, these may be created in any language.

### (i) Limericks

In general, a limerick is a five-line funny poem, rhyming as 'aabba'. Such poems can be composed as a teaching learning tool using the concepts of science. Here is an example involving Einstein's concept of relativity (quoted from Ratcliffe, 2005, p. 208):

*There was a young lady named Bright,*
*Whose speed was far faster than light;*
*She set out one day*
*In a relative way*
*And returned on the previous night.*
[Arthur Buller: 'Relativity' (1923)]

Instead of trying to pen a limerick, which may be somewhat difficult on account of the provisions as stated above, humorous poems in any form and any size may be composed in any language as a teaching learning aid. Let us take an example of the simpler type, highlighting the concepts of good conductor, bad conductor, and heat conduction:

*A brat burns me, held in hand, all cool and calm.*
*When he tries a spoon instead he gets a hot palm.*
*Explain this to me, a poor wooden stick that I am.*

### (ii) Cartoons

Cartoons are very popular among the young and old alike. Then, why not use cartoons to teach science? It is possible to create cartoons using the principles and concepts of science. Here is an example based on the concept of a simple pendulum (Fig. 4) where the swinging bob is ready to offer a free ride to anyone who can identify the forces acting on it.

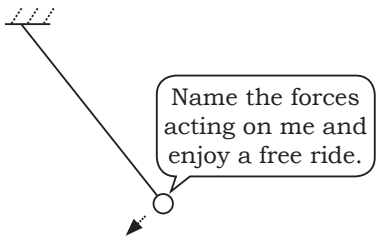


***Figure 4***

We would like to conclude the sequence of themes with some observations on teachers' linguistic mistakes, gleaned from a first-hand experience and how such mistakes may be addressed.

### 18. How teachers can discover their own mistakes

Let us begin with a few actual samples of written statements taken from a lesson plan prepared by a pre-service teacher on the topic of light:

(a) "Can anybody say any sources of light?"

(b) "What happens when the light beam falls on the mirror?"

(c) "Gud afternoon students."

(d) "Plz."

(e) "Today, I want to ask some question which are related to the topic."

A look at the above lines discloses various kinds of mistake the student-teacher has made, including non-standard use of terms like 'good' and 'please'. To give another example of the incorrect use of language, let us quote from an advertisement issued by a private +2 college (Sambad, 2015b): "We are looking Excellent, Energetic, Result Oriented, Committed, Dedicated and highly enthusiastic professionals who are expertise in their respective subjects and experienced in the field of +2 Education." It is not difficult to locate the mistakes in this tag line of the ad.

Let us admit that we all make mistakes in our use of language; teachers and teacher educators are no exceptions. Making mistake is a signature of life. However, if we do not discover and rectify the mistakes, they get deeply entrenched within us with time and we fail to recognise them as incorrect. Language related problems may be of different types, including the trivial variety, slip of tongue, etc. One needs to keep one's eyes and ears open, with enough self-awareness, to able to locate one's own mistakes. If a teacher periodically reflects upon her/his own work with a critical bent of mind, constantly revisits her/his own pronouncements, recalls the faces and expressions of the students in the class, she/he can hopefully discover them. Another way is to have a regular healthy reading/listening habit and reviewing one's own language during these sessions. If given opportunity, some of the students may also point out the teacher's mistakes; in such cases, the teacher ought to accept the same with humility while praising the students. Yet another way is to take help of knowledgeable colleagues. Peer learning can be a powerful weapon for teachers as well as students.

Pointing out anybody's mistake can be a delicate matter and needs to be done with care and caution. For example, instead of blatantly saying, "You are wrong", one may say, "I think it is more appropriate to…..", etc.

### Epilogue

In the current article, we have tried to place before the stakeholders various aspects of the language of science and how to use these in classroom processes for meaningful learning as perceived in constructivist paradigm. Though a certain amount of emphasis has been put on English as the

language of science education in view of its global reach, the underlying tenets may be applied to any language, at any level of education.

From whatever angle we consider, language is important in life. We cannot possibly state it more succinctly than Ludwig Wittgenstein: "The limits of my language mean the limits of my world." (Ratcliffe, 2005, p. 155). Wittgenstein's world includes the world of science, which cannot be entered, explored, or enjoyed without proper language. It is thus an essential need to prepare future citizens of the world well versed in the language of science. To achieve this, teachers directly and teacher educators indirectly need to take a bigger responsibility in helping students to construct their scientific knowledge in terms of concepts, interrelations, and applications, using appropriate language.

All associated with science education will do well to practice a robust reading habit with an eagerness so as not to miss any opportunity to learn, whether language or concept, apart from learning from any other reliable/authentic source. This would definitely enrich one personally as well as professionally. We may conclude with the advice of Sarah Caldwell (quoted in Rayan, 2015): "Learn everything you can, anytime you can, from anyone you can; there will always come a time when you will be grateful you did."

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