

## CHAPTER : II

### FRAMEWORK OF THE STUDY

#### 2.1 TEXTBOOK: A MAJOR CURRICULUM MATERIAL:

In the previous chapter, a brief reference has been made to the nature and importance of textbooks; here those ideas will be further elaborated. Heyeneman et al (1978)<sup>1</sup> in their World Bank assisted study on textbooks of 12 less industrialized countries noted that an investment in textbooks would produce learning gain and they found that the very availability of the textbooks appeared to be the most consistent school factor in predicting academic achievement. Even economists do agree that it is worth investing in Education eventhough its output may be realised only in the long run; investment in textbooks in the process of education can prove its worth even within a year in terms of academic achievement. No doubt, curriculum gets its <sup>full</sup> meaning, when we consider all the curricular materials such as syllabus, textbook, teachers' guide, students' guide, workbooks, films, laboratory equipment & other teaching-learning aids and evaluation tools; but a textbook is a bare necessity for teaching and learning; of course curriculum materials such as educational films, may be academic luxuries for developing countries. Perhaps, except in the case of highly experienced teachers all teachers refer a textbook of one type or the other before they go to classroom; nowadays, even in the case of Higher Education, international textbooks in most of the disciplines have been getting published. In the case of students also, especially at school level, perhaps it will be very difficult to get a student who might not have used one textbook or the other for his studies, except of course, where there are problems of book distribution as in the case of some of the nationalised textbooks; in fact there can be cases, where there may not be any teacher for a particular subject especially in rural schools;

but if atleast a textbook is available, then, students, school authorities and parents will have a sense of assurance about the possibility of learning.

To understand and appreciate fully the role of textbooks in the educational process, perhaps there is<sup>a</sup> need to look into the historical perspectives of textbooks and the next section will deal with the same, in brief.

### 2.1.1 BRIEF HISTORY/EVOLUTION OF TEXTBOOKS IN INDIA:

In connection with the existence, role and position of textbooks in ancient, Vedic period in India (approximately upto 200 B.C.) eventhough we notice the textbook of 'Vedas' in the hand of goddess Saraswati (personification of Education - goddess in-charge of Education in the broadest sense), modern scholars are still not clear about the period during which writing started in ancient India. Can we say that there was no need for them to develop writing during that period, as they were far better in comprehending the more subtle and abstract truths about human existence and other matters in comparison to the modern mind? According to Winternitz (1959),<sup>2</sup>

.....the fact that in the older literacy works there is no mention of manuscripts, is not absolutely a proof of the non-existence of the latter. Perhaps they are not mentioned only for the reason that the writing and reading of them was of no importance, all teaching and learning being done by word of mouth.

A superficial glance at the ancient social order might appear as if the society was primitive; but a deeper study of the highly philosophical literature of that time (perhaps which were put in writing later) would disprove this;<sup>3</sup> because intellectual capacity of the people during ancient period was such that

they could always manage a vast ocean of knowledge by hearing and memorizing; if we look at the curriculum during the period, in addition to the main spiritual curriculum through 'Vedas', there were practical & vocational curriculum (including sciences, medicine, astronomy, mathematics, economics, political science, etc.) and physical & military curriculum. Whether the textbooks had existed or not in the earlier Vedic period, atleast later, certain literatures were developed in written form on various types of materials such as 'tāmrapatra', the palm leaf, barks of the 'bhurja' tree, etc., which, it is taken for granted, were used as textbooks in ancient India in one time or the other;<sup>4</sup> but the interesting information is that during the ancient period the teachers used to dominate the whole system of education and did not use books as a teaching aid, as we do today. During the late Vedic period (i.e. during the time of Manu and Pānini), certain books which could be treated as textbooks came into existence; and certain procedures for textbook writing as well as criteria for its evaluation were developed during those days; but the textbook could never become property of each individual student due to the non-existence of paper and printing technology for large scale production of the same. When the Buddhist period started (after 200 B.C. - of course the Vedic teachings still continued) more and more books came into existence and the concept of preparation and evaluation of textbooks got further clarified.

Education during the medieval period<sup>5</sup> (from 1000 A.D.) in India, mainly had the patronage from the Muslim rulers; in the beginning textbooks used in 'madrasahs' were mainly hand-written and were comparatively poorer in their physical aspects, but content-wise they were good; stress was generally on religious teachings, partly revolved around Islam; hence these textbooks played their own role in making an impact on the majority of Indians; of course during this period also, Education based on ancient Indian culture was also going on to some extent using oral methods as well as hand-written textbooks.

It was only during the British period (1700 A.D. onwards), the role and position of a textbook began to be almost equal to that of a teacher. During early British period, in Sanskrit schools, students were taught, still, either orally or with the help of hand-written manuscripts; the Persian and Arabic schools also, mainly used manuscripts as printed books were not all that in abundance. Since the printing press had already developed in Britain during that period, printed textbooks were being used in British schools for their own children in India. Christian missionaries in India during that period got the credit for establishing printing presses in India and hence to print textbooks, ( of course, mainly with the ideas of religious conversions); but they were not of good quality.

Slowly and steadily, Britishers in India managed to acquire political and administrative stability, took interest in Education of Indians ( of course to fulfill their aim of producing a class of Indian servants), started many educational institutions during eighteenth and nineteenth centuries and hence the production of textbooks in India got a welcome boost; eventhough in the beginning learned Indians resisted this idea of printing textbooks and sympathised with calligraphists, from the beginning of the nineteenth century onwards, Indian societies such as Calcutta School Book Society and the Bombay Native Education Society took a leading role in this connection.<sup>6</sup> In this way, use of printed textbooks in large scale shaped a better system of Indian education.

It may be noted that during British rule in India from 1854-1904, the school textbooks especially in social sciences and English language were British textbooks or their translated versions and bent towards strengthening British rule and weakening Indian cultural tradition, whereas during the period from 1905-1947, it was in the reverse order, because of Indian

enthusiasm in trying to reshape the indigenous education system. Eventhough there was some sort of conception regarding the write-up and evaluation of textbooks, even during ancient period in India, as such, it got systematized with the modern approach in school curriculum, only during British period. In the post-independence period, especially when the spirit of nationalization of textbooks gained momentum, the process of textbook writing, production and evaluation got further strengthened.

During ancient, medieval and even the late British periods, normally, a single teacher of a particular subject and class was the only author of a particular textbook in that subject and for that class; but now the modern trend is to have a panel of authors, and some members of the panel may not be teaching the subject for a particular class, but may be involved in higher level teaching or in related research work; this has got certain advantages especially to reach a higher standard since the knowledge is fast expanding in the modern world, but the disadvantage is that it might become above the level of understanding of the students concerned.

In the post-independence period, Government of India through its various Educational Commissions/Committees has been pointing out the role of the textbooks and the need for the change through proper evaluation and NCERT has been working very hard in this connection as discussed in Ch.I

#### 2.1.2 BRIEF HISTORY OF TEXTBOOKS OUTSIDE INDIA AND ITS INFLUENCE ON INDIAN SCENE:

According to Langenbach (1976)<sup>7</sup>, probably 'Homer's Poems' was the first textbook in old Greece ( c.500 B.C.). During this ancient period, books were very few and valuable; similar to Indian

ancient period books, they were written on leather, bark or leaves of tree, tablets made of mud or even on the surface of stone. Romans used to write on rolls of certain types of fine parchments. During 5th century B.C. in Athens, there was provision for making extra copies of manuscripts for sale.<sup>8</sup> Around 300 B.C., different types of science and mathematics books were produced by the scholars of Alexandria and around 100 B.C., Greek language grammar book was written by Dionysias Thrax.<sup>9</sup>

It was only during 9th century, books started getting produced in large numbers when printing technology was invented in China and later this was introduced in Europe in 15th Century. But it was only during 18th century, printing technology got modernized and large scale production of textbooks played a major role in the process of education. The two World Wars had their own impact throughout the world in one way or the other, on the nature and structure of educational system, curriculum (especially that of science and technology) and hence the textbooks. In the USA, from 1950 onwards, agencies such as American Association for the Advancement of Science (AAAS), National Society for the Study of Education, National Science Teacher Association, National Science Foundation,<sup>10</sup> etc., did a very good job in bringing out several science curriculum projects along with their textbooks for various levels from K.G. to Snr. Sec. Similarly in the U.K., the Nuffield Foundation launched their Science project in 1961-62. In other parts of the world, Canada's Toronto Board of Education and the former USSR's Academy of Pedagogical Science put a lot of efforts in improving the curriculum especially in sciences and hence in the improvement of textbooks. Based on the work done by the above developed countries, developing countries in Asia such as India, Thailand, Sri Lanka, etc., and many African countries such as Nigeria, Kenya, etc., took up the work seriously with all the

devotion and professionalism and brought out new curriculum and attached textbooks in science as well as in other areas too for different levels of school system; in this connection the work done so far by NCERT in India is praiseworthy and this organisation is now in a position to offer consultancy service in the field of curriculum and textbooks to other developing neighbouring countries too.

Thus the above discussions in 2.1.1 and 2.1.2 give a brief picture of history and evolution of textbooks in India and abroad; in India, though there were some efforts in developing the writing and evaluation of textbooks in the past the progress as such was not much; but, during the post-independence period the establishment of NCERT on Sept. 1, 1961 changed the scene. No doubt the modern concept of textbook is different from that of the ancient and the medieval period; broadly speaking the changes are in the following aspects: (1) Now, it is secular in nature, especially in the case of social sciences and language textbooks; it is for the international understanding and peace - this is supposed to be reflected even in science textbooks. (2) It is for pupil-centered system of education in contrast to the previous teacher-dominated periods. (3) It is based on the modern studies in educational psychology and the research findings regarding the content, nature and structure of the discipline; eg., in sciences the textbooks are supposed to mainly activity-oriented. (4) The physical aspects such as printing and binding have improved a lot based on available modern technologies. (5) Textbook publication has become a specialized industry, eventhough nationalisation of textbooks has taken place to some extent.

Now, having known the historical background, in the following sections, the ideal and the realistic or practical, modern concepts of textbook are to be discussed, in the process of establishing a framework for this study.

### 2.1.3 POSITION OF TEXTBOOK IN INSTRUCTION IN GENERAL AND SCIENCE/PHYSICS INSTRUCTION IN PARTICULAR :

Textbook is a part of the curriculum in all disciplines; but because of the nature and structure of sciences (which are activity-oriented) one may think that science textbooks are not that important compared to laboratory aspects; but this thinking may not be always correct in the real situation. This section deals with a few (eventhough there are many), cross section of research evidences to reconsider the position of textbooks in instruction in general and science instruction in particular at various levels including that of higher education in some cases; eventhough this investigation deals with Snr. Sec. Sch. physics textbooks, the available research evidences referred to, may not be specifically for this discipline at Snr. Sec. level; but in general whatever is true for one level and for one branch of science may be true for any other level or any other branch of science, atleast to some extent.

Eventhough textbook is only one of the curriculum materials, whether we like it <sup>or</sup> not, it is a reality that it has taken the position of a major curriculum material, even in developed countries. According to Harmes and Yager (1981),<sup>11</sup> 90 percent of all science teachers use a textbook 95 percent of the time; a textbook exerts an overwhelming dominance over the science learning experience in the U.S. Most of the textbooks do contain the content to be learnt, teacher demonstrations to be done, student investigations to be carried out and the concepts to be formulated by the students; so it may so appear that the 'learning by reading' (which is contrary to the philosophy of science, in which 'learning by doing' is stressed) is taking place; at times a question arises: Can an ideal science textbook replace a teacher and a laboratory (atleast to some extent)? This is a



difficult question to answer but at least one may have to accept the reality that an ideal textbook may have to be considered as an assistant teacher in print, based on number of research studies available in developed as well as in developing countries (Ch.I. pp.14-15); nowadays the Open University System is getting popular throughout the world and it supports the importance of textual material. Learning by reading reflects on one of the important uses of textbooks (Spiegel,1984).<sup>12</sup> Hickey (1984)<sup>13</sup> studied the relationship between textbook structure and student's achievement in seventh-grade science and found that altering standard textbook designs resulted in better achievement. Perhaps throughout the world and especially in developing countries, the textbook has long been a key in the instructional plan of science teachers and is likely to continue to be so, provided the computer do not take over! Yore and Denning (1989)<sup>14</sup> made a study of Canadian secondary school science teachers' reliance on textbooks; the teachers in this study opined that reading too was important to learning science; and these researchers recommended that the science educators and teachers should go back to the reading research, especially the research on cognitive and metacognitive skills since they have found that the textbooks play an important role in science instruction. Regarding the importance and position of textbook in the scheme of formal education, Goel and Sharma (1987)<sup>15</sup> from NCERT write:

.....it may be stated that after the teacher, the textbook is the most important single aid in the teaching-learning process. In spite of the advent of many other teaching aids like film and the TV, the textbook can be expected to remain a major instruction in this country for many years to come.

While concluding that the textbook-used instruction, even in science, is the reality of the schools, there is a need to caution ourselves about the nature and structure of activity-

oriented sciences from one side and the various types of defects that have been found in different science textbooks in the cross section of the world (references for this, will be made in Ch.III) from another side; and also, we should be reminded that there have been studies to show that textbook or instruction through textbooks was less effective than other methods of instruction in some cases and the text-based instruction had to be augmented in some way to bring about significant learning; some meaningful ways to augment text, included, using <sup>study</sup> guides, group discussions and activation of prior knowledge; studies by Skaggs (1988)<sup>16</sup>, Radford (1989)<sup>17</sup> and several other studies support the above views; in addition, we should not forget that any science curriculum gets its full meaning only when it is backed by laboratory activities and not simply by textbook reading; so while accepting the textbook-based instruction as the reality of schools, Baker (1989)<sup>18</sup> says:

.....It strikes me that looking for ways to improve a method of instruction that has been consistently proven to be less successful than other methods is a strange activity for science educators. However many researchers will argue that textbook-based instruction is the reality of schools. My response is that responsible science educators should not capitulate to poor practice because it is the reality. They should continue to argue for good practice and conduct research that makes the implementation of that practice easier for teachers.

While remembering the above precaution, as we have to face the reality, there is a need for us to improve the textbooks at all levels and this is once again to support the rationale for the evaluation of the chosen textbooks.

Having understood the position and hence the need for improvement of textbooks, let us now go into a few more details regarding the same.

#### 2.1.4 SOME MORE DISCUSSION ON STRUCTURE, FUNCTION AND MAJOR CHARACTERISTICS OF TEXTBOOKS IN GENERAL AND SCIENCE/PHYSICS TEXTBOOKS IN PARTICULAR:

Based on several definitions available, some seven aspects of textbooks in brief have already been given in Ch.I (pp.14-15); here those points will be strengthened with some more details with special reference to science/physics textbooks wherever needed/possible.

How does an ideal textbook look like ? This is a difficult question to answer as the very process of education itself is very complicated; according to the American Textbook Publishers' Institute,<sup>19</sup>

.....It should be so simple that the dullest child can read it with ease, yet it should be so scholarly that professors of subject matter will approve it. It should be organised so tightly and ingeniously that each lesson applies what has been taught before and prepares for what is to follow, yet the organisation should be so adaptable and flexible that chapter five or chapter ten may be presented first to fit any local course of study.

Due to so much of development in the field of science as well as in educational science such as pedagogy and psychology, a modern science textbook has become a complex publication. Its characteristics can be noted and commented upon for further improvement only by careful study and classroom use.

Any science textbook is supposed to begin with an introductory section with an attempt to define science, describe the scientific method and expected development of scientific attitude, in addition to an overview of the content of the book and a list of abbreviations/symbols used (through pre-text pages).

Regarding the structure of textbooks, instead of chapters only, there can be a few sections containing several chapters in each; these sections are similar to unit plans built around specific topics; thus a textbook becomes a course of study which can be used in its entirety or with certain deletion or additions according to teacher's and pupil's needs; and its content organisation should set a stage for the year's programme.

In each section or unit, there should be some provision for activity that can prepare the readers for the work to follow; through this activity or otherwise, the readers should be able to recall the past experience (pre-requisite/entry behaviour) in order to establish the foundation upon which the later learnings will be built up; or the introduction may also be in the form of a brief historical background to relate the developments to the present knowledge; or at times, in physics textbooks, the introduction can be even in the form of a challenging problem-solving situation with a mild dose of mathematical computation; in some cases introduction can contain certain advanced organisers too.

The body of each section/chapter should provide printed information in a logical order, which should be sound content-wise too and it should be supported by photographs, drawings (even cartoons to make it more exciting), tables, etc. It should contain supplementary activities such as experiments, demonstrations, additional readings, etc.; throughout the book, references should be made to the original works of scientists atleast through footnotes.

Ideally each section/unit or chapter should end with a list of expected learnings, a list of new terms, summary, questions for formative self-evaluation, suggestions for out-of-school activities and a list of further readings.

Because of large number of scientific vocabulary (due to the expansion of scientific knowledge), there is a great need for an index at the end of the science textbook. In addition, at the end of all the units there can be a concluding review section with overall summative self-evaluation. Expected brief solution to the difficult mathematical problems and answers to all the problems, should also be given at the end; the list of 'Errata' should never be missing in any science textbook; these post-text pages should also contain a list of references for further reading.

Finally, keeping in mind that India is still a developing country, next to the teacher education programme, textbook preparation and production programme is most important, especially in sciences, where highly needed well equipped laboratories may not be there; the textbook can be written in such a way that atleast to some extent, it can give an idea of the missing laboratory apparatus and help to develop the concepts. Now NCERT is seriously thinking of Minimum Levels of Learning (MLL) at each stage of schooling, as NPE (1986)<sup>20</sup> emphasized the need for the same; work has already started for primary stage, mainly for science, mathematics and languages.<sup>21</sup> In this connection, the investigator is of the opinion that for a developing country, a textbook in any particular subject should strictly and clearly reflect MLL; no doubt a standard higher than the set MLL is needed, but let us atleast reach at MLL at all levels for all students especially when we have been talking about the fear of falling standards in education in India (of course this fear is there even in developed countries in general). Textbook is the only thing that can reach each and every student (provided the distribution system is perfect) in any educational process; hence once we set it to MLL, we would achieve a lot.

Discussions made so far in the above section about the textbooks may convince anybody about its importance and hence that of this investigation on physics textbooks; the above discussions also give a general idea of the criteria for evaluation of the textbooks chosen; in order to develop the needed framework further, the next section, mainly deals with the physics education at Snr. Sec. level.

## 2.2 PHYSICS AND PHYSICS EDUCATION IN GENERAL AND AT SNR. SEC. SCH. STAGE IN PARTICULAR:

In Ch.I (pp. 9-14 ), nature and structure of physics has already been discussed. Physics as a distinct discipline within sciences, requires keen observation of phenomena, correct measurements, extensive interaction with apparatus, systematic experimentation to reach at correct conclusion and further predictions; unfortunately, it is considered as a difficult subject for students, not only in India, but even in other developing and developed countries (Shaikh 1982;<sup>22</sup> Bojuwoye, 1985;<sup>23</sup> Cantu & Herran, 1978;<sup>24</sup> Clement, 1982;<sup>25</sup>). Several physics concepts cannot be digested readily by secondary and Snr. Sec. students, perhaps because of the complexity of the logical organization of the concepts, or partly due to the presentation in the textbook and partly due to the very nature and structure of physics. Several research studies indicate that many secondary, Snr. Sec. and even college/university students do have serious difficulties in understanding major concepts and principles of physics in different areas such as, Mechanics, Heat, Electricity, etc. ( Green et al., 1980;<sup>26</sup> Karplus, 1981;<sup>27</sup> Idar & Gaviel, 1982;<sup>28</sup> Cohen et al., 1983,<sup>29</sup> etc.) There are several difficulties in learning of physics such as, abstractness of certain concepts, required mathematical skills, reasoning requirement, etc.; part of these learning difficulties must

be associated with students' level of intellectual development as described by Piaget and Inhelder (1969)<sup>30</sup>; here there may not be any need to go into the details of Piaget's developmental stages, but it is necessary to recall that Piaget's views are acceptable to physics as a discipline within sciences, since its very elements parallel the mechanics of scientific discovery and inquiry (Lieberman & Hudson, 1979<sup>31</sup>); Snr. Sec. students are supposed to be at formal operational stage; but unfortunately many of them do not reach this level; they are found to be still under concrete operational stage (Pandey, 1991<sup>32</sup>). This lack of development is likely to come in the way of prerequisite or entry behaviour at Snr. Sec. school level. Regarding the changes taking place in physics and physics education, Wilson (1988)<sup>33</sup> noted :

.....Change in physics comes quickly, is readily communicated and is widely appreciated. Change in physics teaching however, is long in development, poorly communicated and generally resisted by various special interests in the physics teaching community.

This shows that, until we think of making the physics teaching community happy by providing special and better service conditions, it is very difficult to improve physics education; as such, there is shortage of physics teachers at all levels throughout the world in general, including the U.S.A. and the U.K.

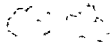

Commenting on the position of physics education Osborne (1990)<sup>34</sup> observed:

.....physics as taught in schools is increasingly a severely distorted view of 'What and how we know'; that many of the examples of 'how things work' are inappropriate; that this perspective of the scientist's world view as presented in schools is simply misleading; that the image it presents is unappealing to the majority of pupils and that changes in technology enables changes in pedagogy.

Language plays a special role in learning and teaching of any subject; perhaps some of the problems in physics education, are due to the extraordinary additional special language that is almost a 'must' for physics; now the next sub-section will deal with a few details about this special language (and of course the role of the general language also, will be treated later in this chapter itself).

### 2.2.1. ROLE OF MATHEMATICS IN PHYSICS:

#### 2.2.1.1 : LANGUAGE OF PHYSICS:

It is well known that mathematics is the natural language for physics and it is also a tool for physicists; it has played a special role, in the historical developments of theories in physics in the areas such as planetary motion & gravitational theory, electromagnetic wave propagation, atomic structure, relativity, quantum & wave mechanics, etc. There have been several international conferences to stress the need for closest links between teaching of mathematics and that of physics at all levels (Fuller , 1972).<sup>35</sup> Throughout the world, perhaps the mathematicians, while revising their curriculum, have not always considered the needs of the students of physics as well as <sup>of</sup> other sciences; they feel that mathematics does have a structure peculiar to itself with its own academic and pedagogical traditions and that there is some danger in any attempt to build a mathematics course merely around the demands of science (Fuller , 1972)<sup>36</sup>; but the question is about the needs of the other clients (i.e., mainly students of physics at all levels) and hence the problem involved popularisation of the discipline; one of the reasons why physics has not been attracting large number of students is the strong fear of mathematics needed in physics. As such it seems that there is no suitable solution for this problem except that of teaching of needed mathematics in the beginning of the physics course



or along with it by the physics teacher himself; but this is not at all an ideal solution for the problem.

There is a need for collaboration in physics and mathematics teaching at all levels and especially at Snr. Sec. level. Whether they like it or not students are likely to have a curriculum which includes a substantial amount of mathematics atleast for five or more years of school education; if this teaching and learning can be viewed as something associated with and beneficial to the learning of physics and other science subjects, then why not have a fine and smooth cooperation (without any ego and superiority over each other) between the teaching, teachers and the textbooks of the two subjects, especially for the benefit of the students, as we all now believe in student-centered educational system throughout the world? Physics provides several important applications of mathematics even at school level; perhaps it is not fair on the part of the mathematics teachers to leave some of the most useful mathematical concepts to be developed solely by the physics teacher.

At Snr. Sec. level some of the most important areas of mathematics that are used in physics are variation, co-ordinate geometry, trigonometry, progression, vector analysis, differential & integral calculus, differential equations, etc.; while teaching these topics, even a mathematics teacher has to know a lot of physics; in the interest of our future physicists, at all levels, if physics teachers, mathematics teachers, physicists, mathematicians, curriculum specialists and educationists sit together at school/college, district, university, state, national and even at international levels to chalk out a special programme in integrated mathematics and physics, it would be a great innovation. To begin with, even at Snr. Sec. Sch. level, the physics and mathematics teachers can have a

sort of special programme of team teaching to co-operate with each other in the interest of their students. Amos (1990)<sup>37</sup> through his extensive research work showed that, whether at school or at college if the teaching of mathematics and physics are correlated (such that there is no mathematical concept that comes across in the learning of physics that has not already been explicitly taught earlier in mathematics) and if a good relationship between mathematics and physics is developed, then there is no fear at all, of mathematics in physics.

Once mathematics is used in physics as the language, it becomes mainly quantitative physics; but there are certain authors in physics who are quite successful in presenting qualitative physics without using much mathematics language but by using simple literal languages (English, Russian, etc). Arons (1982)<sup>38</sup>, based on the research evidence available suggested that there can be more emphasis on the development of a qualitative understanding of physics. According to Osborne (1990)<sup>39</sup>:

.....Nearly all physics education seems to be based on assumption that success with quantitative methods breeds an implicit understanding of qualitative physics. The evidence justifying this principle as the foundation for the edifice of physics education is wanting and the strategy looks seriously like an attempt to put the cart before the horse. Physics courses of the future will need to make a more serious attempt at generating a better qualitative understanding of physics.

If we are doubting the possibility of introducing some of the concepts of modern and contemporary physics in a qualitative way, we should refer to books like Saxton and Fretter (1967)<sup>40</sup> and Stanford (1989)<sup>41</sup>; these books show that it is possible to simplify physics so as to teach and learn it with interest, with minimum mathematics, but without diluting it

intellectually; perhaps these books can help a lot to write physics textbooks for non-mathematics students at Snr. Sec. Sch. level.

#### 2.2.1.2: GRAMMAR OF THE LANGUAGE FOR PHYSICS:

It is of interest to note that when mathematics is the natural language for physics, the grammar of this language mathematics for physics is dimensional analysis (Subramanian et al, 1990)<sup>42</sup>; it has to be used to check physical equations, to derive physical relations, and to convert units from one system to another. Physics textbooks and teachers should explicitly show the use of dimensional analysis to check mathematical equations from algebra, calculus, geometry, vector analysis, etc. Two fundamental rules in the grammar of physics are : (1) Never add or subtract two or more physical quantities that have different dimensions. (2) Multiplication (or division) of physical quantities having different dimensions is allowed. Eventhough poets may sometimes violate the principle of grammar of a language, a student of physics or even a Nobel Laureate in physics cannot violate the principle of grammar of physics. Subramanian et al (1990)<sup>43</sup> have given a very interesting analogy in this connection: Like a devotee who tries to see God in everything and everything in God,<sup>44</sup> a student of physics must try to see its grammar operating in each and every equation not only at the introductory level but also at the advanced level.

Having gone through some of the special aspects of physics as a discipline, a discussion on some of its general requirements will be presented based on the fact that it is still a discipline within sciences.

### 2.2.2: INTEGRATED SCIENCE APPROACH IN SNR. SEC. SCHOOL PHYSICS:

According to UNESCO (1971)<sup>45</sup> publication, Integrated Science is :

.....an approach to the teaching of science in which concepts and principles are presented so as to express the fundamental unit of scientific thought and avoid premature or undue stress on the distinction between the various scientific fields.

Another UNESCO publication edited by Lewis (1972)<sup>46</sup> differentiates between integration and co-ordination in the following way :

.....We shall use the term (integration) in the strict sense of bringing together several subjects in a single course in which scientific concepts are approached uniformly in spirit and method. Carefully planned cooperation among several disciplines is a reduced form of integration but this will be referred to here as Co-ordination.

In the same UNESCO publication, Lewis (1972)<sup>47</sup>, refers to the concept of interdisciplinary subjects:

.....Integration allows for the very natural introduction of intermediate or interdisciplinary subject such as astrophysics, biophysics, biochemistry, microbiology, enzymology, psychophysiology and also the human and economic sciences, which far too long have been dissociated from science teaching. The division of the major traditional disciplines into strict compartments causes these subjects to be neglected, and this is particularly unfortunate since research work at the present time is especially intense in these areas as illustrated by the number of Nobel prizes which have been awarded in chemistry and in medicine and physiology, for example for work using the techniques of physics.

The above three citations are helpful in conceptualizing the three approaches which are of course very much interrelated. The study of science in whatever form, is nothing but man's continuous search for explanations of phenomena in nature and it should be approached as a human activity, where it is artificial to have so many boundaries; the approach to the investigation of scientific problems demands knowledge of one or more fields of science (Bajah, 1983)<sup>48</sup>. As such knowledge is indivisible, but just for the sake of convenience, it has<sup>been</sup> segmented into separate subjects. No doubt, the emergence of different disciplines has increased the efficiency of knowledge generation and has helped in the division of labour among the specialists but due to the following reasons interdisciplinary research works are very essential (Yadav et al 1989):<sup>49</sup> (1) Emergence of new phenomena in the environment such as ecosystem, (2) The cognitive necessities in the course of evolution of certain disciplines (such as biophysics, biochemistry) which demands links between two or more disciplines. (3) The organisational necessity due to increased specialization and narrowing down of perspectives (4) The demands of the society. During the recent 79<sup>th</sup> Session of Indian Science Congress Association, the president Gowariker (1992)<sup>50</sup>, stressed the following points:

.....The last decade of this century is different from even the past decade that has just gone by. The days of thinking exclusively in terms of one's own individual discipline or speciality in isolation are now over. ....

A different kind of pooling up is therefore required of people who, apart from whatever they know, are willing to break new ground on interdisciplinary fronts; and are enthusiastic, energetic, mentally alert and prepared to transform themselves into systems analysts.

At the primary and junior secondary levels, integrated approach has been accepted in principle in most of the countries in the world, eventhough at junior secondary level, teaching of different branches of science by different teachers without really unifying much, has been going on in the name of integrated science; this is mainly because of lack of proper teacher education programme in integrated science; eg., specialist teachers in physics refuse to teach chemistry or biology portion of integrated science, as he has not been trained to do so. So at senior secondary and higher levels one can imagine how difficult it is to think of integrated science teaching; in fact it is not at all realistic to stress fully on integrated science approach beyond junior secondary level; however according to UNESCO publication (Lewis, 1972)<sup>51</sup> at higher levels of secondary education carefully planned co-operation and co-ordination (which are of course a reduced form of integration) mainly among physics, chemistry and biology departments are very much needed; and atleast some form of team teaching may be very appropriate at any rate in the initial stages of development of such course. There are several advantages of doing this type of co-ordination especially in terms of time and resources; atleast in the case of physics and chemistry there are several topics, which are overlapping; eg., topics such as, atomic and molecular structure, interatomic and intermolecular forces, energy changes, kinetic theory of gases, radioactivity etc.; now we have new sub-disciplines such as physical chemistry as well as chemical physics; in fact these are all physical sciences; even biological sciences cannot be left alone, because of new disciplines such as biochemistry and biophysics. Further, when physics has to be taught with relevance to life it cannot escape from getting connected even with non-science subjects such as humanities, social sciences, etc., whereby it becomes real interdisciplinary. The successful application of any branch of science in technology and medicine are nothing

but real situations of integrated, coordinated and interdisciplinary approaches; atleast a few institutions of higher learning have realised the importance of these interconnections: for example, here, the investigator would like to recall his experiences during his four year integrated course in Science Teacher Education at RCE, Mysore (1969)<sup>52</sup>, where Physical & Biological Sciences were taught to all undergraduates for the first two years irrespective of their specialization during the 3rd and 4th years of study. In Nigeria (which is one of the leaders in Africa), University of Ibadan at Ibadan has M.Sc. course in integrated science. Indian Institute of Science, Bangalore has five year integrated Ph.D. programme (after B.Sc.) where highly advanced courses in all branches of science, i.e. physics, chemistry, biology and mathematics are offered to enable the students to pick up interdisciplinary areas of research. Nowadays Indian Institutes of Technology have several ongoing research projects in interdisciplinary areas. At the University of Poona, there is a special department known as Interdisciplinary Studies. Nowadays, University Grants Commission (UGC) has been mounting special grants for interdisciplinary research works in Universities. With the above discussion, perhaps, now it should be possible to get convinced about the importance of integrated approach even at Snr. Sec. level physics; this has to be reflected in Snr. Sec. physics in actual teaching and hence in actual textbooks.

The next section, dealing with the importance of history of physics/science, would further clarify the above issue.

### 2.2.3: IMPORTANCE OF HISTORY OF SCIENCE IN PHYSICS EDUCATION:

Joshi (1963),<sup>53</sup> while addressing the United Nations Conference at Geneva on the application of science and technology for the benefit of the less developed areas, said:

.....Students should be shown how scientific concepts are developed, what has hindered and what has accelerated the pace of science and what science has meant to civilization and the life of man. Such courses should enable the ordinary people to understand the conditions which have stimulated the acquisition of scientific knowledge since ancient times. They can be expanded to include the broad development of ideas, covering the cultural factors and movement that have helped to release man from superstitious beliefs, as also the condition that have retarded the development of human knowledge and civilization.

Mere mentioning of names of scientists and their dates, may not reflect the history of science to the desired extent unless the historical approach supports the relevant biographies of individual scientists, while discussing the relevant topics; the textbooks and the teachers are expected to have biographical approach for the history of science. In connection with the historical approach in the teaching of physics, Boutry (1964)<sup>54</sup> while speaking to an international conference sponsored by International Union of Pure and Applied Physics said:

.....One has to recognise that there are several types of scientific mind. Between the antithetic and complementary Faraday and Maxwell a continuous spectrum of scientific intelligence is spread out for us to examine. One must be reminded that scientists are men and men of their times with their character and their temperaments, their heredity and upbringing, their capacity for love and for strife, all playing a role, large and small, in the formation of their scientific attitudes of thought; I have a suspicion that Volta in his brilliant destruction of Galvani's conclusion was



motivated by a dislike for Galvani the man and Galvani the philosopher. Hate also has some creative value. The dislike of Laplace for Fresnel is another example. It hastened the success of wave theory of light.

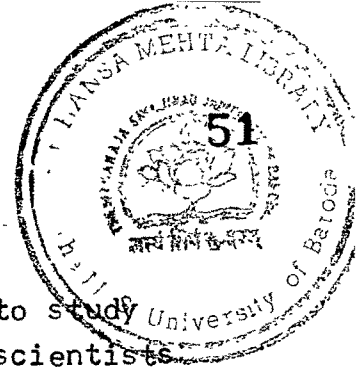
Lewis (1972),<sup>55</sup> in a UNESCO publication relates the teaching of history of science to one of the very broad aims of education i.e., international understanding by stating:

.....The history of science is almost unique in presenting a body of accumulated knowledge which has been discovered by mankind as a whole irrespective of religious, national or even temporal restrictions. In presenting the development of science and the social changes which it has brought about, one can present the total story of mankind as an inseparable part of the world around him in a truly international framework. This is the type of education to which every young person in the world today should be exposed.

Snr. Secondary is perhaps the right stage to convince the youngsters regarding the need for international understanding and peace for the survival of mankind; and exposure to history of science through textbooks and actual classroom dialogues can definitely help to achieve this.

Arons (1988)<sup>56</sup> strongly favoured the inclusion of historical and philosophical elements into introductory physics courses to enable students to get scientific literacy and a deeper grasp of physics.

Regarding the history of science, Indian science textbooks have a special role to play, because the western textbook writers, are yet to recognise the contributions of Indians during ancient period; this is rather unfortunate. There is a



need for Indian scientists and science educators to study Sanskrit language seriously, just as the western scientists depend on Greek and Latin languages to refer to the ancient history of science; our scientists should take the special responsibility of telling the world scientific community regarding our own earlier contributions and this might even help the whole world knowledge to develop further.

In this sub-section it is of interest to note that in 1989, there was an International Conference on the History and Philosophy of Science and Science Teaching at Florida State University in the USA; during this conference Gruender and Tobin (1991),<sup>57</sup> said:

.....Historical components can show something of the pathway by which science has arrived at its present state, with all its ups and downs. It is by means of the struggles and sometimes of the tragedies, that science's very human Aristotles, Galileos and Curies and thousands of others that are less well known, have contributed to modern science. They illuminate the interplay of creative, improvisational, and disciplined efforts, along with the alternation of excitement and elation with disappointment, which lie at the heart of scientific inquiry. These qualities are not unique to science, but are fundamental to all human activities. And they can convey the sense that we stand on the shoulders of those who have gone before us, while those who come after may stand on ours.

Normally history and philosophy of science go together; but in this sub-section only the history of science has been dealt with, as the philosophy of science through its nature and structure has already been partly dealt with in Ch.I (p87-9) and again it will be treated to some more extent in the next sub-section (2.3).

### 2.3 PROCESS AND PRODUCT OF SCIENCE :

In Ch.I (pp.7-9), the nature and structure of science as both a body of knowledge and the process of acquiring it has already been introduced; here those concepts will be strengthened further. At times the process aspect becomes more important than the product because of the very nature and structure of science. The interrelationship between scientific processes and products can be very well understood by referring to the diagram (Fig.1) shown on p.28 (adopted from Carin and Sund, 1970).<sup>58</sup> The progress of science reflects not only the accumulation of knowledge, but also the emergence of scientific attitude and scientific method; the scientific attitude influences the scientific method, which in turn involves certain strategies or steps; but in addition to the execution of these strategies or steps, it depends on certain cognitive abilities of the mind of an individual, which is capable of performing certain activities such as classifying, comparing, hypothesizing, inferring, controlling variables, etc., and these abilities are termed as process skills.

#### 2.3.1 : SCIENTIFIC ATTITUDE :

Whether it is for a child or for an adult, there are certain natural human urges and needs because of which one is driven to seek rational answers to several questions that come to his mind. This urge can be seen very clearly in the case of infants even, who would often take the risk of crawling to any extent, just to reach to a thing which must have attracted him and once he gets it in his hand, he would touch the whole surface of it, observe and enjoy its colour, start chewing it and find out the taste, feel the heaviness of it, if possible break it and hear the sound produced and so so many things with it; but difference between a real scientist and such an infant is that the latter cannot express or record his observation or

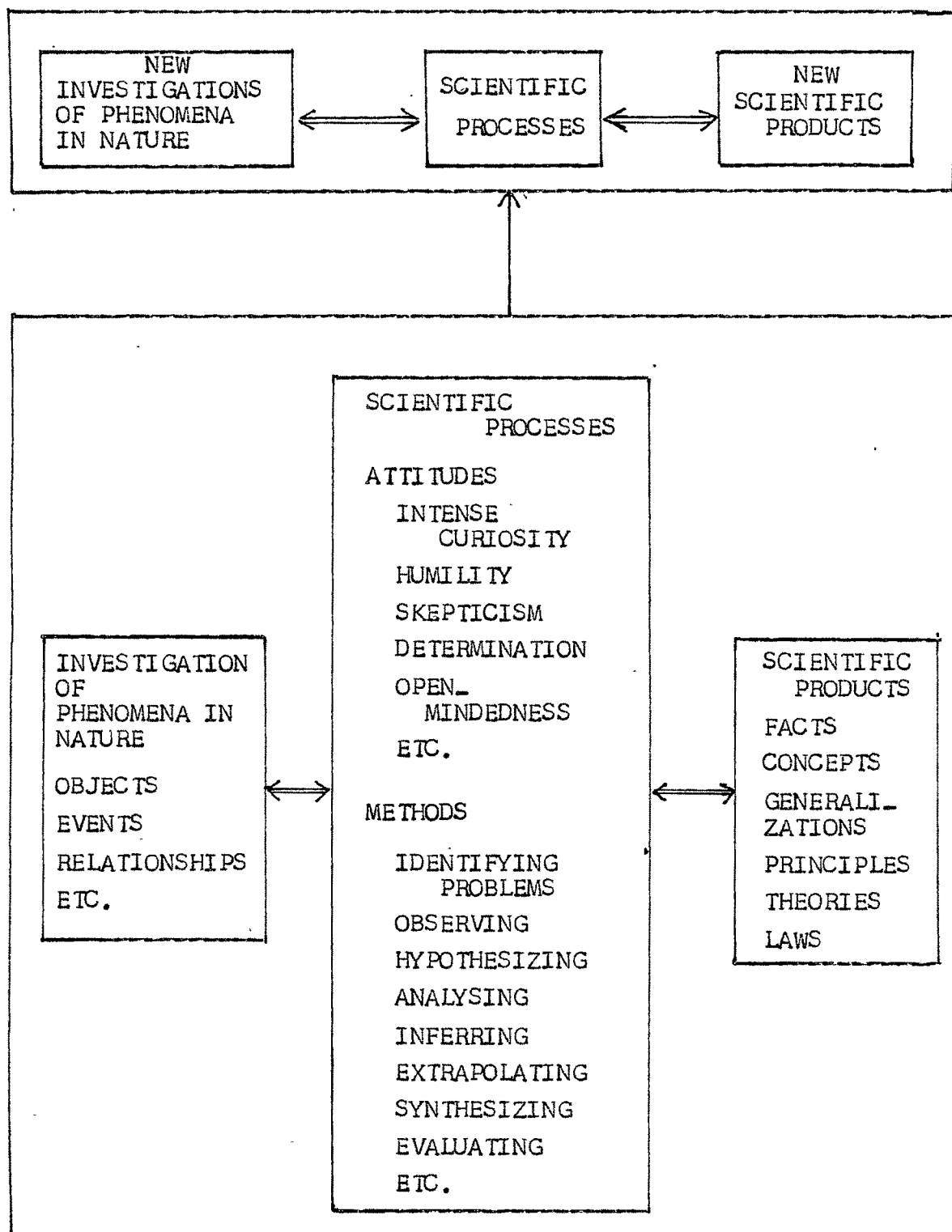


FIG. 1: INTERRELATIONSHIP BETWEEN SCIENTIFIC PROCESSES AND PRODUCTS.

( ADOPTED FROM CARIN & SUND , 1970)<sup>58</sup>

experiences; otherwise an innocent infant left to himself is a real scientist; when he grows as a young child, at the sea shore, he enjoys discovering the texture, colour, size, weight and taste of sand; because all these activities delights the child; if the parents and later teachers are wise enough to observe these natural activities and motivate him further the child can grow and become a good scientist.

As Carin and Sund (1970)<sup>59</sup> put it :

.....This dynamic-almost compulsive-involvement of child or adult investigator searching for answers provides the fuel for vehicle of investigation. Without this attitude of discovery for discovery's sake there would not be scientific inquiry. It is not important that practical applications be found for the results of investigations, for the scientist often is not concerned with nor even aware of the uses for his findings. The sheer joy of discovery and determining knowledge for its own sake is justification and reward enough for studying something.

A scientist is supposed to be a learner throughout his lifetime. He is free to seek, free to be curious and free to inquire. As he continues to know more and more, soon he would discover that he knows so little. He guards himself against his own (human) tendencies to be dogmatic and has to avoid accepting things blindly and unquestioningly. A negative signal is as important as a positive one for a real scientist (Gowarikar, 1992).<sup>60</sup>

Study of science at Snr. Sec. level is a real initiation for somebody who would like to become a scientist. Textbook being the major representative of any curriculum, an ideal physics textbook should be written in such a way that it helps to develop attitudes such as curiosity, creating interest humility, skepticism, open-mindedness, suspended judgement, critical thinking, avoidance of dogmatism, determination, positive approach to failure, etc.

### 2.3.2 SCIENTIFIC METHOD :

Human weaknesses of the type discussed under scientific attitude are likely to disturb a scientist unless he is firm. He has to build safeguards into his methods of research against such human tendencies; i.e. he has to develop scientific attitude upto a satisfactory level. If we go very deep into the details of history of science starting from even the ancient period, we will not fail to notice that several safeguards have been evolved from hundreds of years of works of hundreds of scientists from different parts of the world. These safeguards which have gradually been moulded and formed into the process of science, have been collectively termed as the scientific method (Carin and Sund, 1970).<sup>61</sup> Educationists like Dewey advocate that scientific method and scientific attitude should be among the objectives of formal education. Scientific method is the method scientists follow or should follow while tackling any problem of science and sometimes it is also referred to as problem solving method. It consists of the following major steps:

1. Stating the problem,
2. Formulating hypotheses,
3. Designing an experiment,
4. Making observation and collecting data from the experiment and
5. Drawing conclusion.

While tackling any problem, any individual from any part of the world at any time, follows mainly these steps. Hence whatever has been found out by one individual scientist, can be tested again by any other scientist any where in the world at any given time and this is the speciality of sciences.

No doubt mere memorization of the above steps or mere mentioning of these in textbooks or in the class by the teacher will not help science students to develop scientific method. The textbook authors have to bring in the scientific method within the content in such a way that the students will be tempted or encouraged to use a method of investigation, which cannot be anything other than the scientific method; but to do this, the students need to understand the mental processes involved in the scientific method. Steps involved in the scientific method are mere stages mainly for systematization of the actual carrying out of the work and hence for a systematic reporting of the scientific information later, for any body interested in, to test it. But the science processes (skills) are more important. One may know all the steps involved in playing a game, but unless he starts playing it by putting all his efforts mentally and physically, it is not possible to master the game and so it is with sciences. But there is a need to caution ourselves here, because, strict adherence to the above steps of scientific method may sometimes look very artificial and may curb somebody's creativity. No doubt in general, in any problem solving situation, one need the above steps for guidance, but a scientist who is normally a creative individual may not necessarily follow them in the same order.

As shown <sup>in</sup> Fig.1, scientific method involves several mental process skills. In fact, the steps involved in scientific method get their full meaning only when these skills are fully realised. Now we will go into some more details about these process skills.

### 2.3.3: PROCESS SKILLS:

Actually the nature of science is revealed not mainly by what is found as the 'end product' but more than that in the way it is sought. The development of the understanding of the processes of science as a major outcome of science teaching, has taken a special place in science education. Curricular materials and especially textbooks, should help the students to understand the processes of science. The understanding of the processes of science is one of the most important objectives of the Integrated Science programme. Of course, these process skills become more and more prominent in higher classes. Processes of science can be considered as intellectual tools of the scientists.

In textual materials it is better to shift the emphasis on the acquisition of knowledge to, how the knowledge is acquired; because the phenomenal growth in the knowledge of science which is almost doubling after every decade cannot be fully accommodated in any curriculum or a textbook which represents it. Instead the processes of acquisition of knowledge, which are not very large in number can easily be accommodated in a curriculum, partly directly and partly indirectly.

There are certain <sup>processes</sup> which are common to all branches of science; they are unique procedures and do not change with time; these can be practised as part of daily life; hence, a science curriculum must stress more on these processes than the products of science. No doubt products are useful in daily life as well as in understanding the processes of science and in concretizing the same for pedagogical use; but the understanding of the processes of science are useful both for daily life as well as in furthering scientific knowledge. An Integrated science curriculum is useful as it stresses more on processes of science, rather than on the products.



Physics is an unique branch of science; but even in physics curriculum, there is a need to bring in ideas from chemistry and biology and other branches of science and to 'integrate' them. In the process of integration, it becomes easy to bring in the science processes even within physics.

The behaviours typifying 'scientist at work' are nothing but processes of science; they are the vibrant conditions which characterize science in its research role ( Sund & Trowbridge, 1973<sup>62</sup>).

There are different ways in which these processes have been conceptualized:

- (1) By the American Association for the Advancement of Science (AAAS): Through its 'Science - A Process Approach (SAPA)', it has identified several processes such as, observing, classifying, using numbers, measuring, using space-time relationships, communicating, predicting, inferring, defining operationally, formulating hypothesis, interpreting data, controlling variables, experimenting, etc. ( Carin & Sund, 1970<sup>63</sup>).

In SAPA, there is an emphasis on process skills and de-emphasis on content; of course the content is there - the programme does expect the children to examine and make exploration of noted objects, liquids, gases, plants, animals, rocks, scientific photographs, etc. But in most of the cases, children are not expected to learn and remember all particulars, facts and principles about these objects and phenomena; they are expected to learn how to observe noted objects and their motion, how to classify gases, how to infer internal mechanism in plants

and animals, how to frame hypothesis about unknown phenomena, how to verify hypotheses about animal behaviour, how to perform experiments on the action of different chemicals, etc., (Bhatt, 1988).<sup>64</sup>

- (2) By Gagnè (1966):<sup>65</sup> Gagnè's eclectic views on learning suits very well to interpret learning in physics; he defines science in terms of 'what scientists do'; so, what is taught to children should reflect what scientists do in the 'processes' that they carry out in laboratories. Normally scientists observe, classify, measure, infer, make hypotheses, perform experiments, repeat them again and again to reconfirm what they have found, form theories/laws based on several experimental conclusions, etc.; of course scientists have learnt these things over a period of many years; the above processes are expected to take place in the classroom too; this doesn't mean that all students are expected to become scientists or physicists, even if they do not become, the training in science is expected to be highly useful in their future daily life situations.

- (3) From another point of view, broadly, processes are considered as 'ways of processing information'; these processes grow more and more complex as an individual develops from early childhood onward. The developed individual capabilities can also be called intellectual skills or processes. If these processes are considered as intellectual skills, the question of degree of generalizability of human capabilities arises. Based on Piaget's work, the typical development of intellectual skills is from very concrete and specific to the increasingly abstract and general. Over a period of years

intellectual skills are formed based on the accumulated effects of learning considerable variety of concrete principles. Within each process category, there is an intellectual development which gets increasingly inter-related with other processes; eg., within the processes such as inference and prediction, already the processes such as observing, measuring, classifying, etc., come in.

Now, what follows would be certain details about a few important <sup>process</sup> skills (mainly based on SAPA) which are hierarchical in nature:

- (1) OBSERVING : This begins with identification of objects, their properties, changes in their various physical and chemical systems, making of controlled observations and ordering of a series of observations.
- (2) MEASURING : This starts with the identification and ordering of length, demonstration of rules of measurement of length, area, volume, weight, temperature, force, speed and a number of derived measures applicable to specific physical and biological system.
- (3) CLASSIFYING : Starts with simple classification of various physical and biological systems and develops further with multistage classification, their coding, their tabulation, etc.
- (4) USING NUMBERS : This starts with identifying sets and their members, develops further counting, adding, multiplying, dividing, finding average, using decimals and powers of ten, etc.

- (5) USING SPACE-TIME RELATIONSHIPS: This starts with the identification of rules regarding motion at straight and curved paths, changes in position, etc.; determination of linear and angular speed which come under the study of physics are related to this process.
- (6) DEFINING OPERATIONALLY: In operational definitions one defines the terms based on how they are measured or what they do under certain circumstances, with clearest possible meaning.
- (7) HYPOTHESISING : A hypothesis is an intelligent guess; a causal hypothesis is framed to suggest causes; a hypothesis can be tested to find out whether it has got support or not. Skills such as formulating mental models, theorisation, etc., are somewhat similar to this skill.
- (8) CONTROLLING VARIABLES : This begins with identifying and manipulating variables (independent and dependent) in a description of demonstration of an experiment; it proceeds further to a level at which the students, based on their problem/inference/hypothesis, are actually in a position to conduct an experiment by identifying the variables and describing how those variables are controlled.
- (9) EXPERIMENTING: This is the major "Integrated process"; it is the continuation of the sequence for controlling variables and includes the interpretation of accounts of scientific experiments as well as other activities of stating problems, constructing hypotheses and carrying out experimental procedures, with suitable instrumentation.

- (10) INTERPRETING DATA : This begins with description of data and inferences based upon them; and goes further to construct equations to represent data, then to relate data to the stated hypotheses and to make generalizations supported by experimental findings.
- (11) INFERRING: This is also a kind of guess in an attempt to give explanations for the available observations obtained either from experiments or otherwise.
- (12) PREDICTING : This is based on interpolation and extrapolation of data.
- (13) COMMUNICATING : This begins with description of simple phenomena, variety of physical objects and systems and changes in them for observed result of experiments; here there is a need for the use of formal language.

Having known the processes of science now let us briefly look into the product aspects.

#### 2.3.4 : PRODUCT OF SCIENCE :

This has been treated partially in Ch.I, (pp. 7 - 9 ); however, some of the aspects will be strengthened here to complete the discussion based on the model presented in Fig.1 (p. 53 ). Scientific products are as a result of scientific processes; they are the accumulated, systematized and tested body of knowledge of the fields of science; facts, concepts, generalizations and principles are obtained as a result of hard work of scientists involving the scientific testing of data. (i) A fact must be directly observable and directly demonstrable ( Conant, 1951<sup>66</sup> ); (ii) A concept is an idea generalized from particular and relevant experiences; it is a

reduction of events to a recognizable configuration (Brandwein, 1962<sup>67</sup>). (iii) A scientific principle is a generalization of science involving several related concepts. (iv) A scientific theory is a generalization or body of related principles that explains some scientific phenomena; it is a sort of proposition put forward to explain observed facts but not yet established as true (Daintith, 1976<sup>69</sup>).

Regarding the importance of theory, Thomson (1952)<sup>69</sup> writes :

.....From the point of view of the physicist, a theory of matter is a policy rather than a creed; its object is to connect or coordinate apparently diverse phenomena and above all to suggest, stimulate and direct experiment.

(v) Broadly speaking a scientific law is a scientific theory which has been exhaustively tested and found to be valid with few or no exceptional cases; it is a description of a regularly occurring phenomenon which makes prediction highly possible; of course even in sciences, there are different schools of thought which campaign for different theories and laws; but these controversies are considered as healthy signs of science as they can provoke and stimulate scientists to critically examine and compare their work constantly, and hence progress further and further.

The above section dealing with the processes and products of science has been discussed mainly with the intention of reminding ourselves to make sure that we give equal importance to both in any science curricular activity as well as in curricular aid such as physics textbook; of course as pointed out earlier textbooks cannot do full justification to the processes of science as compared to the products (content);

but depending on the nature of the topic, if the authors have the wide experience in scientific research as well as teaching of the subject at the particular level with the pedagogical background in communication skills as well as in language competency, perhaps, they will be in a position to do justice to the work allotted to them; so, now we will have to go into some discussion on communication aspects in textbooks.

#### 2.4 : COMMUNICATION STRATEGIES IN TEXTBOOKS:

In the previous presentation the reality has already been established that a textbook is an assistant teacher in print; just as a teacher has to communicate very well with his students, so should a textbook. No doubt an effective language is the major aspect in communication in actual teaching as well as in textbook (this will be discussed in the next section, i.e. 2.5), but this alone will not be enough in both the cases. A textbook being a non-living entity unlike a teacher, has to be made more lively by making use of good communication strategies or by making a text to talk. To communicate knowledge to a student, next to the teacher, textbooks are the most common materials. Through good textbook excellent opportunities can be offered to students to explore new dimensions, to acquire graded, interesting and accessible paths for learning. Among the communication strategies in textbooks, questioning styles, presentation of terms and illustrations play a major role at Snr. Sec. level in a discipline like physics; through these strategies, ideally it should be possible to make a textbook to talk or interact with the reader; the following sub-section will deal briefly with the above strategies.

#### 2.4.1 : QUESTIONING STRATEGIES :

Questioning is one of the most important aspects of the process of acquisition of knowledge. The first question in the mind of man might have been sown as the seed of civilization; because it led to the process of thinking and reasoning to unfold the mysteries of nature surrounding man; one question gives rise to another question and it becomes almost the eternal question-answer chain; this chain is the key to cultural enrichment and growth of civilization (Jangira, 1983<sup>70</sup>). Questioning and seeking answer is a lifelong process; perhaps it starts as soon as the child is born and it continues through cumulative learning.

Perhaps it is impossible to find a science teacher who doesn't use questioning in his teaching; because his subject matter, being inquiry-oriented, demands questioning as one of the major communication strategies. By asking question the science teacher assists his students/young scientists in using their mind to inquire. Questioning <sup>has been</sup> used as an important communication technique from time immemorial not only in science but also in most of the disciplines.

Broadly, in a subject like physics, questions can be categorised into the three groups; simple or lower order questions, activity-oriented questions, thought provoking or higher order questions. Factual and rhetorical questions can be considered as simple questions; factual questions are related to questions soliciting direct identification or recall of facts; rhetorical questions are considered as too simple questions as they are just a obvious questions that require no answer. Simple, convergent questions normally use the stems such as what, when, where, how many and sometimes even why, depending on the situation. Activity-oriented



questions in a text can lead to inquiry as well as discovery if they are properly constructed. Higher order questions are not answerable merely from memory; they require some good measure of thought such as organization, making deductions, comparing, contrasting, generalizing, identifying cause and effects, etc.; they can be of divergent as well as probing types: Divergent questions provide for wider responses plus more creative, critical-thinking answers and are useful for inquiry approach (Sund & Throwbridge, 1973)<sup>71</sup>. Probing questions elicit more information, prompt, seek further clarification, increase reader's critical awareness<sup>and</sup> refocus attention as well as direction.

#### 2.4.2: STATUS OF TERMS:

When a physics textbook has to communicate well with the readers, status of technical terms plays a special role. Physics contains several terms in every topic, in connection with facts, principles, theories, laws, activities, etc.; unless these are placed in the proper position in the text, they will fail to communicate systematically to the reader. There can be certain confusions regarding the introduction of different terms in various chapters. Hence there is a need to look into certain details such as finding out whether the needed terms have been defined or not in the chapter when they are introduced, if not, whether they have been defined later in the chapter or in the later chapter; in certain cases, readers may not feel like continuing reading once they come across a term which they do not follow ~~and~~ and thus get frustrated - this affects the effectiveness of the textbook as a learning tool; if the terms are not at all defined anywhere in the textbook, then it becomes a serious problem in communicating to the readers.

### 2.4.3: ILLUSTRATIONS:

Pictures, diagrams, tables, graphs, etc., form illustrative devices in physics textbook; these devices play a very special role in communicating with the readers at Snr. Sec. level as they may cover almost one-fourth of the textbook. There cannot be any single science textbook without any type of illustration because of the very nature and structure of science. In addition to their academic need, they add to the aesthetic appeal that can be made to the reader as well as to the economy in words, space and hence to the volume of the textbook material; in a way, they are to some extent, related to the physical aspects of the textbook, which will be treated separately in another section i.e., 2.6.

Preparation of illustration in any science textbook, requires the services of scientifically oriented artists, eventhough the basic ideas are to be chalked out by the textbook authors themselves. Galvia (1953)<sup>72</sup> from NCERT classified textbook illustration into three categories: expository type (e.g., sketch of solar system), documentary type (e.g., a photograph showing surface of moon) and the artistic type (e.g., cartoons, posters, etc.); all these different types are needed in illustrating different concepts so as to communicate well with the readers. According to Galvia the six major objectives of textbook illustrations are :

1. To provide a visual image of an idea pertaining to the text.
2. To help the reader to develop imagination by giving more information.
3. To present a clear and vivid picture of the unfamiliar objects or figures which are abstract.
4. To help the teaching and learning process.
5. To motivate the reader.

6. To reduce the eye-fatigue of the reader, and to diverge from continuous reading, by providing attractive and interesting reading.

Size and number of illustrations, their different types, their labelling, captioning, location, relevancy, usefulness, attractiveness, etc., are to be found out to say more about the evaluation of the textbooks. Having discussed the role of these special communication strategies, now certain details about the general aspects of the medium of communication, i.e., a language (English language in this investigation) will be treated in the next section.

## 2.5 LANGUAGE ASPECTS OF TEXTBOOKS:

Any language system offers a totality of experiences; one is able to hear it, speak it and respond to it; the objective of any reading instruction is to approximate this totality of intake visually, through mastery of the mnemonic graphic system. According to Ambruster and Anderson (1980),<sup>73</sup> 'considerate' text is one that incorporates a concern for discourse structure, conveys the information and its coherence and makes the relationship among ideas clear enough, in order to bring in logical connection from one idea to the next.

In connection with comprehensibility of a text, Chaudhari (1991)<sup>74</sup> states,

.....comprehensibility of text is a 'meaning-getting' or 'meaning-winning' ability. It is a function of vocabulary, sentence structure, organization, attention and mental processes like memory, comprehension, application, analysis, synthesis and evaluation.

While considering the language aspects, readability of a textbook in the process of comprehension is important especially coherence, unity and audience appropriateness; its structure

at the lower levels of schooling; however, this investigation being connected to Snr. Sec. textbook, no emphasis has been laid for readability because at higher level, it is safely assumed that students may not have much readability problems, having learnt English language for the past ten years and having learnt science and mathematics through English/<sup>medium</sup>textbooks and instruction, in CBSE system. Average sentence length, word length syllable for 100 words, description of style of sentences, etc., are connected with the determination of readability scores of textbooks ( Flesch, 1948) <sup>75</sup>; after determining readability scores there is a need to compare them with the already established national norms at Snr. Sec. school level for science/physics subject; but the investigator is yet to come across such national norms for Snr. Sec. level in India even after going through several related Indian studies and meeting <sup>a few</sup> experts from various parts of the country; moreover establishing such national norms itself is a separate research work which has to be carried out at national level and an individual research worker may find it extremely difficult to carry out such a study. The investigator has come across only one related study in India but for Std. VIII Science - a study to determine readability index of Std. VIII Science text and to find its effectiveness on reading comprehension (Patel, 1976) <sup>76</sup>; but this study may not have the scope to provide national norms at Snr. Sec. level.

English language is an international language; it is essential for science and technology studies at higher level. The lack of proficiency in the English language should not be allowed to inhibit the science and technology student in the pursuit of his profession; luckily a discipline such as physics has got its own structural language, i.e. mathematics; but still there is a need for physicists and especially for

students of physics at all levels to have certain proficiencies in the language, because, after all, they are all part of the society at national/international level in which only language such as English is the common link and they always have to convince the society regarding their work and get feedback from the society itself; but they need not become masters of any language.

In one of the UNESCO publications, Strevens (1969)<sup>77</sup> while discussing the problems of language in the teaching of physics, made a strong plea for closer collaboration between language teaching and science teaching. In connection with English language in advanced modes of thought, he made the following list of grammatico - logical operators, which are commonly used for advanced scientific study:

Type (i) : although, because, if, only, therefore, once, since, unless, until, whenever.

Type (ii) : as a result of, as if, as long as, for the purpose of, if....., then....., in order to, suppose.... then.....since.....then.

Type (iii) : however, nevertheless.

The above lists are not exhaustive, but contain most of the common logical expressions which are needed in understanding of sciences; by the time a student reaches Sec. Sch. level or even earlier, he is expected to have a thorough mastery in usage of the above expressions. Where the language of instruction in sciences, is a second language and not the mother tongue, there can be several problems of language, in understanding of many scientific concepts especially in the process of scientific inquiry. According to Strevens (1969),<sup>78</sup>

the various usages of the term, 'scientific concept' relate to five distinct ideas: (1) To certain linguistic skills common to all advanced academic study, (2) To certain characteristics of the habits of thought of an individual scientist, (3) To a number of concepts prerequisite to science but not unique to it, (4) To practical numeracy which is a special prerequisite and (5) To those concepts which are unique and proper to science or which are inseparable from it. Chances are always there for students to become unsuccessful in sciences, because of lack of general education in the medium of instruction; so textbook authors and teachers should take note of these crucial aspects. A student who has to use <sup>French</sup> /English/ or Russian as a second language from the beginning of his education, has got special difficulties; he has to learn foreign language and science side by side and their rate of progress also should be the same; if the rate of progress in English lags behind the expected rate of progress in science, then the student will have a lot of problems in science.

Physics deals with concepts which are precisely defined; so a physics textbook is expected to convey the correct meaning and the significance of concepts of physics: this requires on the part of the student, a deep knowledge of the language to understand correctly and clearly.

While appealing for closer links between language teaching and science teaching, Strevens (1969)<sup>79</sup> recommends a science-oriented language syllabus in which the choice of linguistic content could be determined by the requirements of the science syllabus. Language teachers and language textbook authors should be aware of the extent to which certain parts of their language syllabus are an essential prerequisite for their student readers who learn science; at the same

time, science teachers and science textbook authors must realise that many of the errors the science students commit are due to inadequate grasp of language rather than inadequate grasp of science on their part as well as on the part of science teachers/textbook authors too; hence there is a need for more collaboration between teachers/textbook authors in science and language. Special language syllabus for science students may not be possible upto Std.X., as it is supposed to be general education; but at Snr. Sec. level this should be possible.

A textbook is one of the important documents in any educational process; so grammatical errors, as such, if there is any, have to be identified in experimental editions of textbooks. Brevity and clarity are two apparently conflicting but supposed to be compromising aspects between the authors who are physicists and the language experts; when the medium is English, which is a foreign language, any Indian textbook author has to be extra careful. Perhaps, it is better, if one of the authors is a specialist in 'English for Science and Technology (EST)' or who has a good background in Science and Technology Journalism or Information Science.

Language specialities such as analogies, metaphors, humors dramatisation, idioms, poems/rhymes, etc., play a very important role even in science learning and hence in science textbooks. There are several research evidences to support especially in the case of analogies and metaphors in learning difficult science concepts (Gee, 1978)<sup>80</sup>, Curtis & Reigeluth, 1984;<sup>81</sup> Duit, 1991<sup>82</sup>. Analogies as well as metaphors express comparisons and highlight similarities; an analogy explicitly compares the structures of two domains and indicates identity of parts of structures whereas a metaphor implicitly compares,

focussing features that do not coincide in two domains. In science, models and analogies are frequently used interchangeably; e.g., the water model of the electric circuit is often called the water analogy. Analogies as well as examples serve similar purposes in any learning process, as both are used to make the unfamiliar, familiar.

Analogical thinking helps a lot in proper conceptualisations as well as in getting rid of misconceptions; if we can make use of an analogical relation between the known and the unknown, it can help students to learn new information easily and even to reject or modify misconceptions. Minstrell (1982)<sup>83</sup> and Clemant (1987)<sup>84</sup> reported their studies in connection with overcoming of students' misconceptions in physics by analogical thinking. If a new phenomenon is too strange or complicated to deal directly, it can be represented in terms of analogies, i.e., in terms of more familiar signs. If we look at the history of physics, Volta and Ampere discovered how to represent electricity in terms of pressures and flows of fluids. Stavy (1992)<sup>85</sup> used analogy to overcome misconceptions about conservation of matter among upper primary children in Israel and showed that analogy is a natural or spontaneous way of avoiding misconceptions.

Other language specialities such as humors, idioms, dramatisation, poems can also play important roles in popularising physics textbooks and hence the teaching and learning. Physicists have also their own aesthetic inspirations and abilities; there are several poems (Smith, 1991)<sup>86</sup> rhymes/haikus (Fraklin, 1990)<sup>87</sup> that are available in topics such as radioactivity theory of relativity, spectroscopy, mechanics, etc. If these can be included in physics textbooks, experts opine they may add a lot to the overall effectiveness of physics teaching and learning.



The above Sections from 2.1 to 2.5 in this chapter, mainly dealt with academic aspects of textbooks. Now the next section will deal with physical aspects.

## 2.6 : PHYSICAL ASPECTS OF TEXTBOOKS:

Apparently physical aspects of a textbook may look non-academic in nature, but if these are neglected, the textbook may fail to impress the reader.

According to Hartley (1990)<sup>88</sup>, there are six important concerns in textbook design namely: (1) page-size and spacing, (2) positioning and spacing the text; (3) type faces and type sizes; (4) emphasis in text; (5) access structures and (6) the design of supportive illustrative materials.

- (1) Page-size and spacing: Decisions about width of margin, column widths, interline spacing, choice of type face and type sizes and the positioning of illustrative materials are based on the size and the orientation of the page. <sup>choice of</sup> page-size is based on a number of factors, the most important being the nature and use of the text; e.g., a pocket dictionary is supposed to be of a small page-size whereas an atlas should be of a large page-size. In many textbooks margins are formed like a picture frame around the information area. Tinker (1965)<sup>89</sup> has reported that the space used for margins can sometimes occupy between 50 to 70% of the page. No doubt, broader margins can sometimes increase the aesthetic aspects of textbook; but if we are more bothered about the functional approach rather than the aesthetic one, it is fair to have a margin of about 10 mm at the top and bottom of the page and a margin of about 20 mm for the left and right sides (Hartley, 1985<sup>90</sup>). Depending on the

page-size, there can be one, two or even three columns of equal width within a page: typographically speaking, this is not very complex. If there are illustrative materials within a page there can be variation of widths of two or three columns.

- (2) Positioning and spacing the text: It is 'technically justified horizontal composition' to see that the text composition is set balanced about a central axis, i.e. there are straight left and right hand edges to the column of print. Many printers often think of an alternative approach in which the text starts from the left hand margin, but gets ragged <sup>at</sup> right hand edge for each column of print but this is 'technically unjustified horizontal composition' in a printed text; to have a technically justified composition, the spacing between the words is varied and words are sometimes broken by hyphenation (especially in narrow column width). There are advantages in 'unjustified' composition too: here the spacing between the words is always same and hyphenation is avoided; there is no need to fill the line with print just because the space is there. In 'unjustified composition', the beginning and the end point for each line is determined by syntactic considerations related to the underlying structure of the text.

The above approach can be taken down the page (vertically) as well as across it (horizontally). If there are same number of lines of print on each page (except for the beginnings and endings of each chapter articles), it is known as 'technically justified vertical composition'; with 'technically unjustified vertical composition', the text may be stopped at the appropriate point in terms of sense or syntax, irrespe-

ctive of the number of lines; in this case, one can also use specified units of space between elements to group and separate related parts within the text. To do all these systematically, there is a need to specify in advance what rules of spacing are to be used in a particular text and one should stick on to these rules throughout. In connection with these two approaches, i.e., technically justified and unjustified, many studies have been carried out to find out which approach would help in the case of young children who are learning to read: Kirby and Gordon (1988)<sup>91</sup> are in favour of the former, but Moon (1979)<sup>92</sup> and Raban (1982)<sup>93</sup> are in favour of the latter; Raban is of the opinion that it is preferable to keep 'carry over' such as 'and' and 'but' at the ends of lines.

- (3) Types faces and Type sizes: The broadest and the most well known classification of type faces is that between those type faces with serifs and those without (Hartley, 1990)<sup>94</sup>. And the choice is mainly based on personal preference. The measurement system used in typography looks too complex; the number of characters (or words) one can have in a line of text and how many lines one can have per column - these two aspects are affected by different type sizes; if the type size is large, it restricts the number of words that will fit within a given column/page width; if the type size allows only four to five words per line, then there cannot be any sensible syntactic groupings in the text composition:
- (4) Emphasis on text: There can be three levels of heading: primary, secondary and tertiary; all the three require specific spatial support but can also be used typographically; e.g., capital letters can be used for primary

headings, upper and lower case bold for secondary headings and italic for tertiary ones; the other types of typographic cueing are underlining and colouring - all these can be used to draw the attention of the readers to particular word or point; in general typographic cueing is used to emphasize different points within text as well as to indicate its overall arrangement. But according to Harley, children do not necessarily understand the cues that adults take for granted and hence there is a need to explain their purpose; he also feels that the multiple cueing can be confusing. Perhaps at Snr. Sec. level, typographical cueing may not be that much confusing; if used systematically it may even reduce the amount of write-up; but instead of taking it for granted that the students can fully understand these typographical cueing which may look like typographical complexities, it is better to explain them in the preface.

- (5) Access Structures : These are devices which help readers gain access to the text, and find their way around it (Waller, 1979)<sup>95</sup>; they are pre-text pages. Students especially at Snr. Sec. level and above may not read a textbook from start to finish and they would like to locate different kinds of information quickly. Researches on access structures such as design of content pages, positioning of page numbers, numbering of paragraphs etc., are not available but, index and bibliography have been already explored (Hartley, 1985).<sup>96</sup> Research<sup>es</sup> on summaries and headings have been carried out by Hartley and Trueman (1982,<sup>97</sup> 1985<sup>98</sup>) and on heading by Wilhite (1989)<sup>99</sup>; but according to Hartley (1990)<sup>100</sup> virtually no study is available on the typographical settings of access structure, eg., on the effectiveness of different typographic<sup>al</sup> settings for headings, summaries of 'boxed asides', etc.

(6) Strengthening the message : To strengthen the communication, devices such as, tables, graphic materials and illustration can be used. Wright (1980)<sup>101</sup> is of the opinion that if students have to use a table successfully they have to (i) understand organization of the table<sup>and</sup> (ii) undergo a process which may involve comparing the numbers within and across the same or different tables. Several research works are available on the merits of different ways of presenting tabular materials and even larger literature on presentation of diagrams, charts and graphs and on effectiveness of illustration too (Hartley, 1990)<sup>102</sup>; <sup>these</sup> can be more effective when they are presented in a simple way and in a consistent manner from page to page; and the illustrations need to be directly relevant and supportive to the text if they are to be effective adjuncts to the communication. Due to aesthetic reasons, some illustrations may help to motivate students but there is no guarantee that such illustrations obviously help the reader to understand the text.

In connection with textbook design, one should note the fact that readers vary (sometimes) very much in their reasons for studying, in their ability and motivation and in their very method of approach; there are differences between 'surface' and 'deep' approaches to studying and reading (Marton & Saljo, 1934<sup>103</sup>; Entwistle & Waterson, 1988).<sup>104</sup> Surface readers are those who skim the text, retain only isolated facts and do not bother about the overall structure or argument presented in the text; whereas deep readers are those who search for the underlying structure of the text, question it, relate ideas to their own entry behaviour and so on. If the textbook authors have to attract deep readers then, before designing instructional text they have to

identify successful learning strategies for reading; Hartley (1987)<sup>105</sup> writes about what are known as 'coherent texts' which are written for specific groups of readers using the language with which they are familiar by including experiences which can be shared by readers and by providing meaningful examples, questions, etc. Textbook design is one of the important ways in which we can make a major improvement in the quality of instruction.

Von Restorff (1933)<sup>106</sup> made a number of studies on isolation effects in verbal learning and she framed what is known as 'Isolation Effect' or 'Von Restorff Effect' which refers to the enhanced recall of a perceptually or conceptually isolated item compared with the recall of a non-isolated item (Panda, 1990)<sup>107</sup>; isolation can be achieved in text materials by several ways such as printing in black, increasing the size of the letters, writing the isolated item on coloured background, underlining, enclosing it by circle or rectangle, etc. This isolation effect influences not only the isolated item but also the entire text material or at least the adjacent items; also the different methods of isolation may have different effect on the overall effectiveness of the <sup>text</sup> material. Science textbooks in general and physics textbooks in particular, need to contain several isolations, especially for new terms, laws, principles, formulae, etc., either by colour or size or by colour and size contrasts. Panda (1990)'s study of isolation effects on learning retention of science text material among elementary children strongly support<sup>s</sup> the prediction that isolation through colour and size contrasts could produce better retention effects in comparison <sup>to the normal black condition</sup> which is generally used to write text in general science; eventhough his study used elementary science text, atleast some of the ideas from his study can be considered while writing textbooks at Snr.

Sec. level also; colour contrasts may not be very much needed, but atleast size contrasts and enclosure of formula using rectangular boxes can be done to increase the effectiveness of physics textbooks.

Within the curricular framework, textbook is one of the devices to help to achieve the goals and objectives of education; to make sure that this achievement really takes place, students have to be helped to evaluate themselves through the textbooks, by giving enough exercises at the end of each chapter; the next section, which is the last one in this chapter will deal with this self-evaluation.

## 2.7 SELF EVALUATION IN SCIENCE/PHYSICS TEXTBOOK:

Instructional Objectives are supposed to be equivalent to evaluation objectives; as the former depend on goals and broad objectives of education, the latter too should depend on the same. Based on the goals and broad objectives, specific behavioural objectives for detailed instruction, for the course, unit, chapter and hence for each and every topic are to be developed by the instructor and the textbook should reflect on these, as it is an assistant instructor in print. While thinking about behavioural objectives, in modern system of education, it has become almost a custom to conceptualise them in three different areas or domains, namely cognitive, affective and psychomotor, based on the well known taxonomy of educational objectives, developed by Bloom et al (1956).<sup>108</sup>

Cognitive objectives deal with cognition - of knowledge, understanding or comprehension, application, analysis, synthesis and evaluation; these sub-levels or sub-domains form a hierarchy as such and knowledge alone is considered

as lowest level of learning; application and other levels (normally considered and termed together for the purpose of simplicity) are the higher levels of learning. In science, these cognitive objectives especially under knowledge sub-domain can very well reflect on product aspects of science in a typical textbook; but ideally they are supposed to take care of the other sub-domains within cognitive as well as the other two domains also, as they deal with process aspects of science directly, or indirectly sometimes. Affective domain objectives are those that deal with feelings, interests and attitudes, whereas the psychomotor objectives concern behaviours involving physical manipulation of apparatus, skill development, proficiency in using tools, instruments, devices, etc. A science textbook may not enable students to achieve objectives in psychomotor domain but it can at least help them achieve the same mainly inside the laboratory, or sometimes even outside through certain activities in school or at home. Science process skills (Sub-section: 2.3.3) and psychomotor domain skills are interrelated, and an ideal science textbook is supposed to help the development of both by producing suitable enabling activities.

In any educational process, the process of evaluation is a must; formative evaluation is the important aspect in the continuous process of evaluation and this ends with the summative aspect which decides the certification. Even though evaluation is the responsibility of teachers and other managers of educational process, an adolescent student at Snr. Sec. level if he is self-inspired, can think of self-evaluation. A Snr. Sec. textbook, as a reliable and important assistant teacher in print in the real and practical sense, should be not only a friend, philosopher and guide to the student readers, but also an assistant examiner in print or a guide to the process of self-evaluation formatively and continuously and hence summatively too.



In any educational set-up, when we think of <sup>a</sup> large number of students, normal probability curve suggests that most of the students are expected to be average with a few at the top and the bottom. At Snr. Sec. level, in a course such as physics, perhaps there is no way a dull student can manage and even an excellent physics textbook will not be useful to such students. But an ideal textbook should help student readers at the top by providing additional problems to solve which should be really challenging, exciting and highly motivating to develop their talents further.

In this chapter with sections from 2.1 to 2.7, an attempt has been made to develop a framework to carry out an evaluation of the physics textbooks mainly by looking at objectives from 1-6; seventh objective (i.e. to study students', teachers' and experts' opinions), is to get a sort of external validity for the finding from the other objectives; and the last objective is expected to reflect the overall evaluation based on the CBSE syllabus, NCERT's guidelines for textbook evaluation and hence NPE (1986) in general. Several studies have been quoted in this chapter to support the conceptualised framework; review of the related research works in India and abroad, in the next chapter, would help to delineate the methodology for the evaluation process of the physics textbooks.

REFERENCES

1. Heyeneman, S.P., Textbooks and Achievement - What We Know, - World Bank Staff Working Paper, No.298; Washington,D.C.: The World Bank, 1978.
2. Winternitz, M.A., A History of Indian Literature., Calcutta: University of Calcutta, 1959, pp.29-30., In Goel,B.S. & Sharma, J.D., A Study of Evolution of the Textbook, New Delhi: NCERT, 1987, pp.14-15.
3. Goel, B.S. & Sharma, J.D., A Study of the Evolution of the Textbook. New Delhi: NCERT, 1987, pp.8-15.
4. Ibid, pp.15-17
5. Ibid, p.201.
6. Ibid, p.202.
7. Langenbach, M., "Textbook", The Encyclopedia Americana, International Edition, New York: Americana Corporation, Vol.26,1976,-p.563.
8. The New Columbia Encyclopedia (3rd Ed.).., New York: Columbia University Press, 1975, p.333.
9. Robins, N.H., A Short History of Linguistics, London : Longmans, 1967, p.30.
10. Carin, A.A., & Sund, R.B., Teaching Science Through Discovery (2nd Ed.), Ohio: Charles E. Merrill Publishing Co.,1970, pp.63-65.
11. Harmes, N.C. & Yager,R.E., What Research Says to the Science Teacher, Vol.3, Washington, D.C.: National Science Teacher Association No.471-14776; 1981., In Renner,J.W. "Understandings and Misunderstandings of Eight Grades of Four Physics conceots"Journal of Research in Science Teaching (JRST), Vol.27 (1),1990, p.35.
12. Spiegel, D.L. & Wright, J.D., "Biology Teachers' Preferences in Textbook Characteristics, Journal of Reading, Vol.27(7), 1984, pp.624-628.

13. Hickey, M.C., "Textbook Structure and Test Performance in Seventh Grade Science", Boston University, 1984, Dissertation Abstracts International (DAT), Vol.45(7), 1985, p.1975-A.
14. Yore, L.D., & Denning, D., Implementing Change in Secondary Science Reading and Textbook Usage : A Desired Image, a Current Profile, and a Plan for Change. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA, ED 305270, 1989, March 30-April 1. In Baker, D.R., "A Summary of Research in Science Education - 1989", Science Education, Vol.75 (3), 1991, p.362.
15. Goel, B.S., & Sharma, J.D., op. cit. p.4.
16. Skaggs, L.P., "The Effects of Knowledge of Maps and Pictures on the Acquisition of Scientific Information", Doctoral dissertation, Texas Christian University, 1988 DAI, 49, p.4049-B, 1989.
17. Radford, D.L., "The Effects on Student Achievement of the Use of Extended Verbal Analogies in High School Biology Textbooks" Doctoral Dissertation, University of Georgia, 1989, DAI, Vol.50, 1989 p.1618-A.
18. Baker, D.R., "A Summary of Research in Science Education - 1989", Science Education, Vol.75(3), 1991, p.367.
19. Quoted in Shores, L., Instructional Materials - An Introduction for Teacher., New York: The Ronald Press Company, 1960, p.49. In Goel, B.S., & Sharma, J.D., A Study of the Evolution of the Textbook, New Delhi : NCERT, 1987, p.4.
20. Govt. of India, National Policy on Education (NPE) - 1986. New Delhi: Ministry of HRD, 1986.

21. NCERT, Minimum Levels of Learning at Primary Stage - Report of the Committee Set up by the Ministry of HRD, Govt. of India, 1991. New Delhi: NCERT, 1991.
22. Shaikh, Z.A., "Attitudes of Nigerian Students Towards Physics" Journal of Science Teachers' Association of Nigeria, Vol.20(2), 1982, pp.158-163.
23. Bojuwaye, O., "Crisis in Science Classroom - Poor Enrolment of Secondary School Students in Science Subjects and its Implication for Science Teachers.", Journal of Science Teachers' Association of Nigeria, Vol.23 (122), 1985, p.214-219.
24. Cantu, L.L., & Herron, J.D., "Concrete and Formal Piagetian Stages and Science Concept Attainment", JRST, Vol.15(2) 1978, pp.135-143.
25. Clement, J., "Students' Perceptions in Introductory Mechanics", American Journal of Physics, Vol.50(1), 1982, pp.66-71.
26. Green, B.F., McCloskey, M. & Caramazza, A., "The Relation of Knowledge to Problem Solving, with Examples from Kinematics". Paper presented at the NIE-LRDC Conference of Thinking and Learning Skills, Oct.,7-10, 1980., In Pandey, N.N., Perspective in Physics Education: A Piagetian Approach, New Delhi: Classical Publishing Co., 1991. p.22.
27. Karplus, R., "Educational Aspects of the Structure of Physics", American Journal of Physics, Vol.49(3), 1981, pp.238-241.
28. Idar, J. & Ganiel, U., "Diagnosis of Learning and Reasoning Difficulties of IX Grade Physics Students as a Basis for Developing Remedial Teaching Methods," Abstract of paper presented at the 55<sup>th</sup> annual NARST Meeting, Lake Geneva, W1, 1982, In Pandey, N.N., Perspective in Physics Education: A Piagetian Approach, New Delhi: Classical Publishing Co., 1991, p.22.

29. Cohen, R., Eylon, B. & Ganiel, U., "Potential Differences and Current in Simple Electric Circuits: A Study of Students' Concepts", American Journal of Physics Vol.51(5), 1983 pp.407-412.
30. Piaget, J. & Inhelder, B., The Psychology of the Child, New York: Basic Books, 1969.
31. Liberman, D. & Hudson, H.T., "Correlation Between Logical Abilities and Success in Physics", American Journal of Physics, Vol. 47(9), 1979, pp.784-786.
32. Pandey, N.H., Perspective in Physics Education : A Piagetian Approach : Doctoral Thesis, B.H.U., Varanasi - ICSSR supported publication, New Delhi: Classical Publishing Co., 1991, p.171.
33. Wilson, J.M., Changing the Introductory Physics Sequence To Prepare the Physics Student of the 1990s: Proceeding on the Conference on Computers in Physics Instruction, Ed: Risly, J. & Carolina; Addison Wesley, 1988, In Osborne, J., "Sacred Cows in Physics - Towards a Redefinition of Physics Education", Physics Education (U.K.) Vol.25(4), 1990, pp.189-196.
34. Osborne, J. "Sacred Cow in Physics - Towards a Redefinition of Physics Education", Physics Education (U.K.) : Vol.25(4), 1990, pp:189-196.
35. Fuller, A.W., "Physics and Mathematics" in Lewis, J.L., (Ed.) Teaching School Physics - A UNESCO Source Book., Paris : Penguin Books - UNESCO, 1972, p.151.
36. Ibid, pp.152-160.
37. Amos, K. La., "Do Students Find Physics Easier to Learn Without Mathematical Problems", Physics Education (U.K.), Vol.25(4), 1990, pp.202-204

38. Arons, A.B., "Phenomenology and Logical Reasoning in Introductory Physics Course", American Journal of Physics, Vol.501, 1982, pp.13-20.
39. Osborne, J., op. cit.
40. Saxon, D.S. & Fretter, W.B., Physics for the Liberal Arts Students, New York: Holt, Rinehart & Winston, Inc.1967.
41. Stanford, The Time and Space of Uncle Albert, London: Faber & Faber., 1989.
42. Subramanian, P.R., Gnanapragasam, B., & Janhavi, G., "The Grammar of Physics" The Physics Teacher, (USA) Vol.28(3), 1990, pp.174-175.
43. Ibid.
44. Srimad Bhagvad-Gītā, Ch.6. 30.
45. UNESCO, Planning for Integrated Science Education in Africa, Report of a Regional Workshop, Paris: UNESCO, 1971,  
In Adeniyi, E.O., "Curriculum Development and the Concept of 'Integration' in Science - Some Implication for General Education", International Science Education Section, Science Education, Vol.71(4), 1987, pp.525-526.
46. Lewis, J.L. (Ed)., Teaching School Physics, - A UNESCO Source Book, Paris: Penguin Books - UNESCO, 1972, p.109.
47. Ibid, p.110.
48. Bajah, T., Teaching Integrated Science Creatively. Ibadan : Ibadan University Press (Nigeria) 1983, p.2.
49. Yadav, M.S., Menon, S.B. & Kumar A.P. Educational Research Methodological Perspective (Eds): Yadav M.S. & Mitra, S.K., Baroda: CASE, M.S.University, 1989, pp.152-153.
50. Gowarikar, V., Science, Population and Development, Presidential Address at 79th Session of Indian Science Congress Association held at M.S.University, Baroda, 1992, p.10.

51. Lewis, J.L. (Ed.) op.cit, p. 109 & 111.
52. RCEM (NCERT), B.Sc. Eds Four Year Degree Courses in Teacher Education, Science & Technology, Mysore; Regional College of Education, 1965.
53. Joshi, A.C., Science and Technology for Development, Geneva: United Nations, 1963, In Lewis J.L.(Ed.), Teaching School Physics - A UNESCO Source Book, Paris: Penguin Books - UNESCO, 1972, p.128.
54. Boutry, G.A. "The Historical Approach in the Teaching of Physics", Why Teach Physics, Michigan: The MIT Press, 1964, In Lewis, J.L.(Ed.), Teaching School Physics - A UNESCO Source Book, Paris: Penguin Books - UNESCO, 1972, p.127.
55. Lewis, J.L. (Ed.), op. cit. p.126.
56. Arons, A.B., "Historical and Philosophical Perspective Attainable in Introductory Physics Courses". Educational Philosophy and Theory, Vol.20(2), 1988, pp. 13-23.
57. Gruender, C.D., & Tobin, K.G., "Promise and Prospect", Science Education, Vol.75(11), 1991, p.3.
58. Carin, A.A., & Sund, R.B., op. cit., p.6.
59. Ibid.
60. Gowariker, V., op. cit., p.5-6.
61. Carin, A.A. & Sund R.B., op. cit., p.7
62. Sund, R.B., & Trowbridge, L.W., Teaching Science by Inquiry in the Secondary School, 2nd ed. Columbus (USA) : Charles E. Merrill Publishing Co., 1973, p.3.
63. Carin, A.A., & Sund, R.B., op. cit., p.67.

64. Bhatt, P.C., Science Process Skills in Teaching and Learning, New Delhi: Commonwealth Publishers, 1988, pp.7-10.
65. Gagne, R.M., Conditions of Learning, New York: Holt, Rinehart & Winston, 1966.
66. Conant, J.B., Science and Commonsense, New Haven, Conn : Yale University Press, 1951.
67. Brandwein, P.F. in Schwab, J.J. & Branswein, P.F., The Teaching of Science, Cambridge, Mass: Harward University Press, 1962,p.111.
68. Daintith, J. (Ed.), A Dictionary of Physical Science, London: MacMillan Press & Pan Books, 1976, p.292.
69. Thomson, J.J., in Copant, J.B., Modern Science and Modern Man. New York: Colombia University Press, 1952,p.91.
70. Jangira, N.K., Technology of Classroom Questioning, New Delhi: National Publishing House, 1983, p.1.
71. Sund, R.B., & Trowbridge, L.W., op. cit.,pp.111-119.
72. Galvia, S.P., Illustrations for Textbooks, New Delhi: NCERT, Dept. of Teaching Aids, 1953.
73. Ambruster, B.B., and Anderson, T.H., The Effect of Mapping on the Free Recall of Expository Text (Tech. Rep. No.160); Illinois: Centre for the study of Reading, Uni. of Illinois. Urdrana, 1980 In Chaudhari, U.S. "Comprehensibility of Text, A Pedagogical Perspective", University News, Vol.XXIX (38), 1991,p.5.
74. Chaudhari, U.S., "Comorehensibility of Text, A Pedagogical Perspective", University News, Vol.XXIX (38), 1991, p.5.



75. Flesch, R., "A New Readability Yardstick", Journal of Applied Psychology, Vol.32(3),1948, In,Okpala, P.N., "Readability of Physics Textbooks used in Secondary Schools in Oyo State, Nigeria ", Journal of Science Teachers' Association of Nigeria,Vol.21(1),1982, p.103.
76. Patel, D.N., "A Study of Readability Indices of the Prescribed Science Material for Class VIII and the Effectiveness on Reading Comprehension", Ph.D. Edn. SPU - 1976, Second Survey of Research in Education, Buch, M.B. (Ed.) Baroda: SERD, 1979, p.301.
77. Strevens, P., "Problems of Language in the Teaching of Physics" Paper presented at the Rehovot Conference on Science and Education in Developing States, 1969. In Lewis, J.L.,(Ed), Teaching School Physics - A UNESCO Source Book, Paris: Penguin Books - UNESCO, 1972,pp.58-59.
78. Ibid, p.59.
79. Ibid, pp.66-67.
80. Gee, B., "Models as a Pedagogical Tool: Can We Learn From Maxwell ?" Physics Education, (U.K.),Vol.8, 1978.
81. Curtis, R.V., & Reigeluth, C.M., "The Use of Analogies in Written Text", Instructional Science, Vol.13, 1984, pp. 99-119.
82. Duit, R., "On the Role of Analogies and Metaphors in Learning Science", Science Education, Vol. 75(6), 1991. pp.649-672.
83. Minstrell, J., "Exploring Condition of an-Object" The Physics Teacher (USA),Vol.10. 1982 , pp.10-14.

84. Clement, J., "Overcoming Students' Misconceptions in Physics-- The Role of Anchoring Intuition and Analogical Validity" In Proceedings of the International Seminar on Misconceptions & Educational Strategies in Science & Mathematics (Vol.III) Cornell University, 1987, pp.84-97,  
In Stavy, R., "Using Analogy to Overcome Misconceptions About Conservation of Matter", JRST, Vol.28(4), 1991, pp.305-313.
85. Stavy, R., "Using Analogy to Overcome Misconceptions about Conservation of Matter", JRST, Vol.28(4), 1991, pp.305-313.
86. Smith, G.O., "Poetry in Ice and Spectra - Thoughts on Poem by James Clerk Maxwell" The Physics Teacher (USA) Vol.29(7), 1991, pp.430-435.
87. Franklin, B., "Physics Haiku"  
The Physics Teacher, Vol.28(3), 1990.  
p.80.
88. Hartley, J., "Textbook Design: Current Status And Future Designs" International Journal of Educational Research, Vol.14(6), 1990, pp.533-541.
89. Tinker, M.A., Bases for Effective Reading, Minneapolis, M.N.: University of Minnesota Press, 1965.
90. Hartley, J., Designing Instructional Text, (2nd ed.), London: Kogan Page, 1985, In Hought, H.A. & Willan, D.M. (Eds), The Psychology of Illustration, (Vol.2), Instructional Issues, New York: Springer Veslay, 1985.
91. Kirby, J.R. & Gordon, C.J., "Textbook Design and Comprehension: Effects of Reading and Information Processing Strategies" British Journal of Ednl. Psychology., Vol.58(3), 1988, pp. 287-300.

92. Moon, C. "Categorization of Miscues Arising from Textual Weakness", In Muackray, D., (Ed.), Growth in Reading , London: Ward Lock International, 1979, pp.137-146.
93. Raban, B. "Text Display Effects on the Fluency of Young Readers", Journal of Research in Reading, Vol.5, 1982, pp. 7-28.
94. Hartley, J., op. cit., 1990.
95. Waller, R.H.W., "Typographic Access Structure For Instructional Text", In Kolen, P.A., Wrolstad, M.E., & Bomma, H. (Eds). Processing of Visible Language, New York: Planum, 1979, pp. 175-187..
96. Hartley, J., op. cit., 1985.
97. Hartley, J. & Trueman, M. "The Effects of Summaries on the Recall of Information : Five Experimental Studies", Human Learning, Vol.1(1), 1982, pp. 63-83
98. Hartley, J. & Trueman, M., "A Research Strategy for Text Designers - The Role of Headings"., Instructional Science , Vol.14(2) , 1985, pp. 99-155.
99. Wilhite, S.C., "Headings on Memory Facilitators : The Importance of Prior Knowledge". Journal of Educational Psychology, Vol.81(1), 1989, pp. 115-117.
100. Hartley, J., op. cit. 1990.
101. Wright, P., "The Comprehension of Tabulated Information : Some Similarities Between Reading Prose and Reading Tables" N.S.P.I. Journal, Vol.IX(8), 1980, pp. 25-29.  
In Hartley, J., "Textbook Design: Current Status and Future Designs", International Journal of Educational Research, Vol.14(6), 1990.
102. Hartley, J., Op. cit. 1990.

103. Marton, F.P. & Saljo, R., "Approaches to Learning". In Maston, F., Hounsell, D., & Entwisth, M. (Eds.), The Experience of Learning, Edinburgh: Scottish Academic Press, 1934, pp.36-55.
104. Entwisth, M.J., & Waterson, S., "Approaches to Studying and Levels of Processing among University Students", British Journal of Ednl. Psychology, Vol.58(3),1988, pp.258-265.
105. Hartley, J., "Typography and Executive Control Processes in Reading". In Britton, B.K. & Glyn, S.M. (Eds.), Executive Control Processes in Reading, Hillsdal, M.J.: Erlbruum, 1987, pp.57-79.
106. von Restorff, "Uber die virkung Von Berichsbildungn" in Spurenfeld". Psychologie Forschung, Vol.18, 1933, pp. 299-342., In Panda, B., "Isolation Effects on Learning and Retention Among Elementary Children", Journal of All India Association For Educational Research, Vol.1, 1990, p.22.
107. Panda, B., "Isolation Effects on Learning and Retention Among Elementary Children", Journal of All India Association For Educational Research, Vol.1, 1990, pp.22-29.
108. Bloom, B.S. (Ed.) , A Taxonomy of Educational Objectives : The Classification of Educational Goals, Handbook I, The Cognitive Domain., New York: Mc Kay, 1956.