A Position Paper
Joint Science Education Panel (IASc, INSA, NASI)

Executive Summary

The enormous potential for India to become a leading knowledge power in the coming years can be realized only if our younger generation has opportunities for all-round good education and training, especially in science and technology. Unfortunately, however, the present state of higher education in the country is rather poor. In order to make it more relevant to the changing needs of society and thus to propel India to a position of leading knowledge power, we need massive investments as well as well-planned radical changes in our higher education system. The Science Academies had, earlier in 2006, submitted a detailed proposal to the Planning Commission for investments in higher education in Science during the XI Plan period and modalities for utilization of the resources. The three Science Academies of the country are now proposing changes that are needed in our college and university education in Sciences to meet the emerging challenges.

The major drawbacks of our current post-school science education are: (1) compartmentalized teaching/learning of a few sub-disciplines of science, (2) time and energy wasted in sequential admissions to BSc, MSc and PhD programmes, (3) repetition of topics at BSc and MSc levels, (4) poor laboratory facilities and consequent poor training of students in experimental methods, (5) little exposure to research methodologies, (6) limited options for movement between science and technology streams.

Keeping these in view, it is suggested that a new 4-year B.S. programme should be introduced, at select institutions to begin with, which the +2 pass students can join. Subsequently, the interested and competent BS qualified students can directly join a dual degree MSc, PhD programme. If they wish to leave in between, they can do so with an M.Sc. degree alone. Those qualifying the 4-year BS or the ongoing BTech can move from basic science to technology and vice versa for further education, leading to MSc/MTech. and/or PhD.

Considering the diversity of students’ needs, their interests and capabilities on the one hand, and the varied infrastructure and competence available in the large number of teaching institutions in the country on the other, it is suggested that the existing 3-year BSc, 2-year MSc and the integrated MSc or integrated PhD programmes may also continue for the time being.

The +2 qualified students would thus have any of the following options for higher studies in science and technology:

4-year BS followed by PhD in basic sciences, with a provision for early exit with MSc degree or dual degrees after completion.
4-year BTech. followed by PhD in basic sciences.
4-year BS followed by MTech./PhD in professional (Technology) field.
3-year BSc followed by 2-year M.Sc. and then PhD or 3-year BSc followed by integrated MSc-PhD.
3-year BSc followed by 2-year B.Tech.
5-year integrated MSc followed by PhD.

Vocational Courses

It is essential that all the existing BSc and MSc as well as the proposed 4-year B.S. programmes follow the semester pattern with credit-based courses. The BSc or BS curricula must provide a broad-based learning rather than segregating 'Bio-' and 'Math-' groups very early. In addition, opportunities must be available for students to take at least 15% of credits through courses in other science disciplines and in social science/arts, etc. All science courses must have good 'hands-on' laboratory training. The teaching programmes should also include courses in research methodology and communication skills.

There is a strong need for substantial improvement in the quality and quantity of teachers at college as well as university levels. Massive efforts for continuing training of teachers to keep them abreast of developments in science are required. A strong experimentally-oriented science education system would require massive investments for developing the necessary infrastructure in universities and colleges across the country.

1. Introduction

The unprecedented economic growth in India during the current decade, increasing acknowledgement of the importance of education and knowledge by its large population, and the incremental investments made over the past several decades in expanding the national base of education at all levels, should be expected to provide the necessary impetus for our nation to become a knowledge-leader in the near future. However, as has been widely discussed in recent years, the present state of higher education in general, Science in particular, is far from satisfactory. To actually realize the enormous potential of our youth power, several radical changes are required.

The Science Academies, which represent the best talent in scientific research and education in the country, have been concerned with issues that afflict higher education and research in Science in the country. It is obvious that multi-pronged approaches and strategies are required not only to restore the quality of science education and research but to actually enhance it to continually increasing levels to be internationally competitive.

On the one level, there is an urgent need for a quantum increase in the investments in science education so that our teaching institutions can provide a stimulating and rewarding atmosphere which would be conducive to creative learning. At another level, we need to bring about significant changes in how we train our young minds so that they emerge from their institutions of learning as creative and innovative individuals ready to face the challenge of successfully competing with and taking a position of leadership in the ever-advancing fields of science and technology. It is obvious that the present state of our educational institutions is far from satisfactory to generate the quality and quantity required for the nation to be anywhere near the leading edge. We not only need a large number of new universities and colleges to provide the required increase in quantity of young people trained in different branches of science and technology, but we also need to significantly improve the quality of training.

On an earlier occasion, the Science Academies had deliberated upon the minimal requirements of investments through public funds to improve the "hardware" that would facilitate the desired increase in quantity and quality of trained human resource and submitted their considered proposals to the Planning Commission (please see Appendices I and II). It is clear, however, that mere increase in investment cannot improve the quality. Therefore, the Science Academies also have examined the actual manner of training of the young human resource in science and technology. A Discussion Meeting, jointly sponsored by the three Science Academies, was held at Bangalore on 24 May 2008. This was addressed by the Presidents of all the three Academies and was attended by Vice-Chancellors of several universities, Directors of IISERs, representatives of Directors of IITs, and a large number of science educationists and researchers from different parts of the country. A large number of them participated in the day-long discussions. The present report has been prepared on the basis of these extensive discussions.

2. The Existing Basic Science Teaching Programmes

A student enters the science stream of learning during the later part of school education, the +2 stage in the current pattern. The state-funded higher secondary education system, although in need of much improvement, has nonetheless contributed significantly to the volume of students receiving their higher secondary (10+2) certificate with basic sciences as major subjects.

The most common pattern prevalent all over the country for post-school (10+2) teaching programmes in basic sciences requires the students to go through a 3-year BSc course followed by a 2-year MSc course before they can join a PhD programme.

The BSc programmes offered in different central/state/private universities have several variations. Most of them follow the annual system, although a few have switched over to the semester pattern. The BSc (pass) degree typically involves study of a pre-defined combination of three subjects in all the years, although in some cases during the third year of BSc, only two subjects, out of the three studied earlier, are taught. Several universities offer Honours at BSc: in this case, the student studies a pre-defined set of three subjects in the first two years and only one subject in the third year for Honours (or Major) in that subject. In some universities, the Honours subject is defined in the first year of BSc itself such that the student studies three subjects all through the three-year course but with greater emphasis on the subject chosen for Honours. In yet another variation, some BSc degrees involve study of only one subject all through the three years.

In most of the universities, the three-subject combination at BSc is compartmentalized among three major science streams, viz., the ‘Bio’ (or ‘Medical’) group, the ‘Maths’ or ‘Physics’ (or ‘non-Medical’ or ‘pure science’) group, or the ‘Geo’ group, with little freedom for the students to learn across these groups. For example, those opting for ‘Mathematics’ or ‘pure Science’ stream, study Physics, Chemistry and Mathematics or Statistics or Computer Science but nothing of Biology while those opting for the ‘Biology’ stream cannot study Physics, Mathematics, Statistics or Computer Science, etc.

On completion of the BSc degree, the student seeks admission to the 2-year MSc (annual or semester) often with a specialization in the final year. A majority of the MSc courses are also confined to one subject only, with the possibility of a student opting for a particular branch within the subject as ‘special paper’ or ‘major elective’. Barring a few cases, there is hardly any avenue available for students to learn something outside the subject in which they qualify for the MSc degree. In most cases, there is only a little component of research in the MSc curricula. Some institutions have also started integrated MSc-PhD programme for BSc degree holders, with a provision for graduation with MSc degree after successful completion of the course work.

The newly instituted IISERs and a few other universities/colleges have, in recent years, started 5-year integrated

MSc programmes in which the student gets admitted after the +2 stage. These courses are better organized in terms of the broad-base and flexibility of course combinations that a student can choose from. These courses provide scope for some 'hands on' experience of research.

For a variety of reasons, most of the existing BSc programmes provide only little of actual laboratory exercises and little scope for any exploratory ("soft" research) activity on the part of the student. Consequently, students hardly learn "how to practise science".

3. Limitation of the Present System

In terms of our present structured (school to college to university) education system, the undergraduate science education (BSc) is expected to:

1) Prepare students to take up an academic/professional career requiring more specialized learning/training at the post-graduate level. This stream is expected to provide the pool of well-trained teachers/researchers and thus the BSc degree is to be followed by MSc, which for those desiring to pursue a career in teaching at higher levels and/ or a career in research needs to be followed by PhD.

Or 2) Provide training to students so that they may find gainful employment (self- or otherwise) – BSc may be a terminal degree in such cases or may require a diploma in specific field/vocation.

In recent years, a substantial increase in the number of students at the higher secondary level, resulting from the much-desired awareness for learning and also because of growth of the country's population, has led to a mushrooming of privately run schools. The generally poor funding of state-run schools on the one hand, and a lack of rigorous monitoring, and the unwillingness of the management of private schools to reinvest in the system on the other, have been detrimental to quality education at the higher secondary level. The science stream of school education has suffered the most due to these factors. Another drawback of the science education curriculum at 10+2 level is its highly compartmentalized structure into the Physical Sciences and Biological Sciences streams. A student of the former category can graduate by studying only mathematics, physics and chemistry as science subjects, along with one language course and one additional subject which could be, for example, physical education. Similarly, for a student of the Biological Sciences, the common choice is to go for biology, chemistry and physics with any additional subject and a language course. The biology students do not study mathematics and vice versa. Moreover, in recent years, specialized subjects such as biotechnology, bioinformatics, information technology and computer science, etc., are being introduced as substitutes for the fundamental subjects like biology, physics or mathematics. This practice is hollowing the foundations of a core science education. Instead of introducing these specialized courses, the need of present times is to ensure that students learn all basic courses of science, viz., physics, chemistry and biology, in addition to mathematics. This would enable them to adapt to the changing scenario of science education in which the rigid disciplines of the past are diminishing rapidly.

The avenues of higher education available to these school science graduates of the country to continue in S&T, whose numbers run into several lakhs per year, fall into several categories such as:

1) A four-year professional course in engineering (BTech./BE) offered by IITs, NITs and the state and privately run colleges.

2) A four and a half-year (+ 1 year internship) medical degree (MBBS) offered by the central, state and private medical colleges.
3) A five year Master of Science (MSc or MS) course offered by some of the IITs, all IISERs and a few central/ state universities.
4) A three-year Bachelor of Science (BSc) course, usually with a clear bifurcation of physical science and biological science streams, offered by central and state universities and a myriad of colleges. This is followed by a 2-year MSc.

While a small fraction of the graduating higher secondary students get the opportunity to avail option #1, or #2, and still fewer the option #3, a majority of them either drop out of a career in S&T or go for option #4, which culminates in a BSc degree. However, the poor structure of BSc programmes, compounded by poorer teaching and facilities, fails to prepare the students for a gainful employment or launch a promising academic career. This, combined with the unprecedented demand for engineering, and to some extent for medical graduates, is steering a large number of higher secondary science students to take option #1, although only a fraction of them actually succeed. More unfortunate, however, is the fact that a majority of those who succeed in this option actually end up in private engineering colleges, which have mushroomed all over the country but have very limited facilities and capabilities. Obviously, most of these institutions do not offer a meaningful engineering/medical education. Thus a large proportion of students graduating from such engineering colleges face great difficulty in finding employment even with much lower remuneration than those graduating from the established seats of learning such as the IITs and NITs.

The present system of science education at post-school level thus fails to fulfil the basic objectives because:

- It does not provide a holistic learning of sciences due to paucity of time and rigid course structure;
- The compartmentalized learning does not adequately prepare the student, either for research or for pursuing a career requiring general skills in science;
- In most institutions, the student is required to select the honours/major subject at the time of joining a BSc programme before realizing his/her real interest in the subject;
- There is little training of young students in methods of scientific enquiry;
- There is almost complete neglect of Humanities in most of the BSc curricula across the country;
- Lot of time is wasted every year because the actual teaching time is just about 6 months a year. The summer months are rarely utilized in a meaningful manner. Further, after finishing BSc, the students waste about 6 months in securing admission to MSc (often after writing yet another set of entrance examinations);
- The Master's course that follows the BSc programme significantly overlaps with BSc curricula, which makes the students disinterested;
- Typically 10 or more years are required after school to get PhD. This makes the choice of a career in science less attractive to young children and their parents, because other fields provide more rapid employment opportunities;
- The switchover from science to technology/engineering and vice versa is generally not possible due to the unequal durations of BSc (3 years) and BTech. (4 years) programmes.

While the above problems stem partly from poor pedagogy and poor infrastructure at the colleges/universities, a major part relates to the way our teaching programmes are structured.

The rigid bifurcation insisted upon at the first non-professional science degree course (BSc), is severely limiting the competence of our country's science graduates in the current global scenario of interdisciplinarity. An extreme of this compartmentalized education is the introduction of specialized courses like those in biotechnology, genetics, bioinformatics, nanotechnology, etc., at BSc level. In most of these programmes, the students hardly learn the basic science part and thus remain incompetent for basic as well as technological applications.

It is clear that the contemporary cutting edge questions in life sciences cannot be solved without knowing the concepts, tools and techniques employed by professional physicists and chemists and without developing adequate computational and mathematical skills. It becomes extremely difficult to demarcate specific subject boundaries in many emerging areas of science and technology, like those in smart materials, nanomaterials, micro (molecular) electronics, biotechnologies, biosensors, etc,. More broadly, it is difficult to distinguish between electronics and physics, materials science and chemistry, and between biology and biomaterials. Without understanding the basics of one field, it is no longer possible to exploit the possibilities offered by another. One of the major reasons for the relative poor innovative R&D activity in the country indeed is the lack of in-depth interdisciplinary teaching and the required level of flexibility in moving from one discipline to another.

4. The Country Needs Flexible and Multi-Choice Education System in Sciences

In view of the great diversity of socio-economic, cultural and political structure of India, it is not possible to meet the highly varied educational requirements of its increasing numbers of youth through any one system of course structure. It is clear that India contributes substantially to the pool of youth in the world and its share will increase in coming years. To harness this enormous potential in youth power, it is essential that we prepare our new generations well to meet the existing and emerging challenges so that not only are their aspirations satisfyingly fulfilled but the country as a whole can indeed become a knowledge power.

The rather monolithic structure of our current under-graduate and post-graduate teaching programmes has failed to prepare youth with qualifications required even in current times. This failure would only magnify in coming years unless our education system is radically and urgently changed to provide the much needed flexibility as well as integration.

There are varied ambitions and reasons for a student to seek admission to the science stream at post-school level. It is unfortunate but true that a majority of students enrolling for a BSc degree across the country do so because they fail to get into a professional stream. Only a small proportion joins the BSc programmes by choice. If our BSc teaching programmes were really challenging and better organized, many of those who initially drifted into this stream without a choice, would subsequently begin to enjoy what they are studying and thus turn into creative individuals. Unfortunately, the present dispensation often frustrates even those who came to this stream initially by choice.

Any change in the existing archaic system of science education must take into consideration the diverse requirements of the aspirants as well as the highly disparate capabilities of the range of academic institutions that are engaged in imparting such education.

The students' expectations can be broadly grouped into the following:

1. Most students who join the science stream as under-graduates are neither willing to nor capable of finally taking up an academic career (R&D and/or teaching). For a large number of students, the Bachelor's degree would be the terminal degree and therefore, it should prepare them to earn their livelihood respectably, through jobs (private or public), business, etc.
2. Those who wish to choose science as a career (moving into R&D activities and/or teaching or science administration) need to go for PhD.
3. Appropriate vocational training courses should be available for those holders of Bachelor's degree who are inclined to be vocationally creative.

The range of academic institutions is also very wide in terms of expertise and capabilities of their academic and other support staff on the one hand, and available facilities and funds on the other:

1. Some research institutions have highly competitive and accomplished faculty and good infrastructure. However, while most of them have PhD programmes, only a few have PG programmes and almost none of them are involved in UG teaching.
2. The newly established IISERs and the IITs or NITs are better endowed in terms of infrastructure, faculty and academic/administrative autonomy.
3. Several of the central and some of the state university departments have long-standing programmes of UG and PG teaching; however, the quality of infrastructure and faculty is, by and large, not up to the required level. Many of the central universities offer only PG and PhD programmes, while some also offer UG programmes in their science departments. Each university has different sets of rules and regulations but the individual departments do not have the desired levels of academic autonomy.
4. Many state universities provide affiliation to large numbers of colleges scattered around the geographical area of the given university. These colleges have a wide range of infrastructure capabilities, ranging from very poor to tolerable, but they are bound by the common academic and administrative procedures defined by the affiliating university. In addition, depending upon the geographic locale, e.g., urban vs rural or semi-urban, the overall quality of facilities and capabilities also varies, although the student population, in terms of their academic capabilities, need not vary in the same proportion.
5. A large number of colleges (imparting UG as well as PG education) have been recognized by the UGC as autonomous colleges. They have some degree of academic and financial autonomy although their degrees carry the name of an affiliating university.
6. A large number of institutions (private as well as public) have been recognized as "deemed to be university" or private university. They enjoy considerable autonomy and often can develop good infrastructure but in the absence of the required level of academic audit, the quality of education imparted at many of them is below the minimal expected levels.

The categories 4-6 contribute maximally to the pool of graduates produced in the country. Given the wide disparities between different types and centres of learning and the varying requirements of the students, it is obvious that no one pattern can meet all the requirements. We need to provide for different programmes that cater to different needs and can be imparted by institutions of varying capabilities. There has to be a greater degree of autonomy and flexibility with a more powerful and vigilant performance audit of the institutions.

5. Proposal for Introduction of a 4-Year Post-School BS Programe followed by PhD

Keeping in view the above considerations and following extensive discussions, the Science Academies are of the view that the country needs to introduce a Four-year BS programme following which, the successful graduates can directly join PhD programmes. Some of the obvious advantages of the 4-year BS, which provides eligibility for enrolment into PhD programmes, are the following:

- Compared to the 3+2 years of BSc and MSc programmes, a continuum of 4 years provides for better time-management for teaching in a holistic manner. This would permit a broad-based training (including in humanities or other fields of individual choice) of science graduates, which is essential for developing a true knowledge society.
- Students (and parents) do not need to worry about one more entrance test and they may have better options for jobs after 4 years than after 3+2 years under the present system.
- The 4-year BS programme has international equivalence and many of the bright young students, who opt to study abroad because of the reduced time and greater flexibility, would find it equally good within the country and this would reduce "brain-drain".
- Since the BTech./BE courses are of 4 years' duration, the 4-year BS programme would facilitate the possible switchover from science to technology/engineering and vice versa.
- Any deficit in the 4-year programme in relation to PhD-related research can be taken care of in the course work for PhD.
- In the short term, such a 4-year BS programme may be a high quality preparatory first part of a research programme leading to a PhD. Over a longer term (say 10 to 15 years) it can replace the present 3-year BSc and be regarded as being as attractive as a BTech, because such graduates may have wider employment opportunities on account of much better training in science.

6. Flexible and Multi-choice UG and PG Science Education Programmes

While it is widely agreed that a 4-year B.S. programme offers a better, and therefore, preferable pattern, it is also clear that given the above noted wide disparities and local constraints, the country should have multiple models for post-school science education so that prospective candidates can choose what they prefer from amongst those available. Accordingly, the following multiple modes are suggested:

1. A new 4-year BS programme which permits entry to PhD programmes, without the need for a Master's degree;
2. The existing 3-year BSc + 2-year MSc + PhD;
3. Integrated or dual-degree PhD programme for the 3-year BSc degree holders;
4. The 5-year Integrated MSc programme (as in some universities and IITs and in IISERs) for the +2 qualified students followed by PhD.

The following provides some general guidelines about each of the above programmes.

The 4-year Bachelor of Science (BS) programme (new proposal)

1. Those passing out of the +2 level in science stream will be eligible for admission. On successful completion

of the 4-year course, they would be eligible for seeking admission to PhD programme, since it is expected that the 4-year period would prepare them as well as or better than the conventional 3-year BSc + 2-year MSc courses and any deficit can be made up by course work during PhD.

2. The BS/BTech. degree holders can switch over to PhD in areas of science different from their Major/Honours subject as well as in Engineering/Technology if they qualify in the relevant tests, etc.
3. The BS programme would be a credit-based semester system in all engineering/science colleges/institutions.
4. BS students will opt for a Major subject in the last two years.
5. There should be transfer of credits from within and between institutions.
6. Students in final year of BS should be eligible for NET and equivalent tests.

The common core courses during the first four semesters should cover basics in:

- Mathematics
- Physics
- Chemistry
- Biology
- Earth Sciences
- Humanities and Social Sciences
- Computing skills
- Communication skills
- Workshop practices
- Laboratory practices

Subsequently, the BS students would acquire substantial knowledge/skill in one subject (Major) and get additional training in at least one more subject (Minor). The students would be exposed to research early on, through term papers and projects.

It is important to emphasize that everything need not be taught and the basic philosophy should be to arouse the curiosity of students and encourage them to undertake projects on various topics. Emphasis should be on learning and research. Overall, there should be a multi-disciplinary training.

Additionally, it is very important to have courses which inculcate a sense of societal responsibilities, a spirit of teamwork and innovation, and leadership qualities. Programmes such as NCC, NSS, sports, outreach and lectures on history of science are ideal to achieve these goals. In addition, a critical and balanced approach to an account of the Indian Heritage in the sciences, mathematics and technology, accompanied by an appreciation of our art, literature and culture, need to be developed and communicated to students.

A general model for distribution of credits in different subjects during the 8 semesters of this programme is given in Appendix III. Appendix IV provides further suggestions/explanations about the proposed 4-year BS programme.

PhD Programme Following the 4-year BS.

1. The first year of PhD should be largely devoted to course work (deficit courses as well as advanced course

in the specific area of research), with the combination of courses being selected in consultation with an Advisory Committee.

2. Completion of PhD would entitle the candidate to get a dual degree: MSc as well as PhD.
3. Those who wish, may exit with an MSc degree after successful completion of course work and a dissertation.
4. BS and BTech. can be equivalent for crossover for PhD in science and technology/engineering.
5. Flexibility to be provided for time required for completion of the course work and for selecting combinations of courses.
6. It is desired that each doctoral candidate publishes at least 2–3 original research papers in peer-reviewed journals prior to submission of the PhD thesis.

Restructuring of the Existing Three-year BSc and 2-year MSc Courses

In view of the diversity of needs of students and the capability of teaching institutions, it is desired that the existing 3+2 pattern of BSc and MSc courses may also continue for some time. However, as discussed earlier, these courses need to be restructured to provide integrated learning, rather than making the students specialise too early without being adequately exposed to the basics. Therefore, the following measures, which can be implemented by institutions ranging from those with limited infrastructure to those which are better endowed, are suggested in order to improve the quality of teaching and learning in the conventional BSc and MSc courses

1. Semester system: A semester system with internal class assessment (30–50%) followed by end-semester examinations (70–50%) should be followed since credit-based courses allow flexibility in combinations that a student may select out of several possibilities.
2. First year of the three-year BSc programme should include courses in all major disciplines of Sciences, so that all students learn the basics of ‘physical’, ‘life’ and ‘earth’ sciences. These courses should advance the student’s understanding beyond what is expected to have been learnt at the +2 level. ‘Deficiency’ courses may need to be planned for those who may not have studied Mathematics or Biology at the +2 level.
3. In the second year, a student may select three main subjects; however, about 15–20% of credits should be earned through courses from other streams (e.g., a student of ‘Physics/Maths’ stream may take some courses in Biological/Earth sciences and vice versa).
4. During the third year, a student may select one subject (Major or Honours subject) out of the three studied in the second year. Again, 15–20% credits should be obtained through courses in other streams. These should also include courses designed to improve “skills” like computer programing, statistics, instrumentation (optical/electronic), etc.
5. ‘Interdisciplinarity’ should not be at the cost of ‘classical’ concepts in any of the core subjects, which need to be identified and carefully included.
6. The course contents (and teaching) should be geared to develop concepts rather than merely provide ‘information’ for memorizing.
7. The field of biology has expanded enormously in the last few decades and will continue to expand for a few more decades. The perceived potential of several of the so-called ‘modern’ areas in Biology has led to introduction of specialized courses like biotechnology, bioinformatics, genetics, etc., at the under-graduate level as well. However, in the absence of integrative learning of basics of biological systems and adequate laboratory work, such courses, in general, produce large numbers of graduates with little knowledge, and

therefore, mostly unemployable. Therefore, BSc degrees in such specialized subjects (e.g., biotechnology, bioinformatics, genetics, nanotechnology etc.) must be stopped.

8. All science courses must include 30 to 40% credits in laboratory and field work (where applicable as in Earth sciences and some areas in Biological sciences) and the laboratory exercises should be planned in such a manner that students have opportunities for 'hands-on' training, and a certain proportion of practicals should be 'open-ended' so that students can learn to be innovative/exploratory. The 'open-ended' exercises may also be in form of 'projects', which should include, besides actual study, preparation of a formal report. Care must be exercised to ensure that the practicals do not become 'rituals' or 'demonstrations', and project reports do not get 'copied' from one batch to the next. Adequate laboratory facilities and competent teachers are essential to ensure student's continued interest in learning and practising science.
9. It is also desirable that all students learn language, at least from the viewpoint of presentation of data, etc., in scientific reports/papers. In addition, the students should be encouraged to take some extra credits through courses in history of science in ancient and modern India, and/or in fields of Arts, Social Sciences, Performing Arts, etc., to help develop a more integrative personality.
10. To encourage communication skills, each student should be required to give at least one seminar on a current topic in the third year of BSc.
11. The MSc courses should also be semester- and credit- based and should include ~15% credits through courses outside their main subject. Depending upon the available expertise and facilities, special papers or major electives may be offered. The laboratory exercises must involve hands-on training rather than only demonstrations. Further, to inculcate the habit of asking questions and interpreting data, several of the experiments conducted by MSc students must be "open-ended" which do not have a pre-defined result.

Integrated BSc-MSc course (5 years)

1. In many situations, it may be desirable to have a 5-year integrated MSc course in which students enrol after +2 direct for the MSc degree. Such integrated courses have the advantage of maintaining continuity from one level to another thus avoiding lots of repetitions that happen in the two separate degree programmes. The time thus released can be effectively used for more wide-based learning and some research experience.
2. The integrated courses should be allowed only in University/College departments which are really active in research so that the students are exposed to quality laboratory exercises and research environment from first year onwards.
3. As suggested for the regular BSc (and MSc) courses, the integrated programmes must follow semester system with wide-based curricula and sufficient flexibility in selection of courses by individual students, keeping in view their own likings/deficits, etc.
4. Appropriate provision may need to be provided for exit, at the end of the third year with a BSc degree, to those students whose cumulative grades are below a certain point (e.g., equivalent to 60%) or for those who do not wish to continue to get MSc degree and feel that BSc may be their terminal degree. This will ensure that only those serious about higher studies continue to get MSc. Likewise, a provision of 'lateral entry' of bright students who completed a regular 3-year BSc degree into these MSc programmes also may need to be made.

Integrated PhD Programmes

1. Institutions with good research capabilities may offer integrated or dual-degree PhD programmes for students who have successfully completed the 3-year BSc programme. The course work, equivalent to 3 semesters

(i.e., ~15 courses), should provide advanced learning broadly related to the field of study and deficiency courses, if required.

2. Option may be provided for exit, with MSc degree, after successful completion of the 2 years of course work and a research project.
3. Flexibility in time required for completion of a degree and in combinations of courses to be provided.
4. It is desired that each doctoral candidate publishes at least 2–3 original research papers in peer-reviewed journals prior to submission of the PhD thesis.

Technology/Engineering Courses for 3-year BSc Degree Holders

1. The 3-year BSc graduates, who do not wish to pursue an academic career but have an inclination for technological applications, may join a 2-year BTech/BE programme. This will enable them to meet a variety of requirements in industry, defence and educational institutions where scientifically trained technical personnel are needed.
2. BSc graduates with a strong science/mathematics background would be ideal for a two-year BTech in computer science and engineering, electronics and communications engineering, biomedical engineering, biotechnology, etc.

Vocational Courses

1. Appropriate vocational courses may be designed and introduced in areas that can provide direct employment. This may be based on a good analysis of local industrial and other requirements. Some general examples are: (i) Bio-Medical Laboratory Techniques; (ii) Bioinformatics; (iii) Biotechnology, (iv) Computer Applications (Hardware and/or Software); (v) Electronics, (vi) Laboratory Techniques (for Physics/Chemistry labs), etc.
2. In addition to the above, the various vocational training courses offered by the ITIs also need to be strengthened and diversified so that those getting trained in such courses can find meaningful self-employment.
3. These courses need to be so designed that the students may be ready for gainful employment. These courses may be available to students after school (+2) or after 3-year BSc or the 4-year BS depending upon the nature and level of training and should provide a diploma certificate.

Summary Recommendations

In summary, as shown in the flow diagram in *Figure* 1, it is suggested that the following multiple options should be available to a student coming out of school through science stream:

1. 4-year BS
2. 3-year BSc
3. 5-year integrated MSc
4. Admission to PhD after 4-years of BS or BTech, with a provision for early exit with MSc/MTech degree, or dual degrees after completion.
5. Admission to PhD after 3-year BSc followed by 2-year MSc
6. Admission to PhD after 5-year integrated MSc

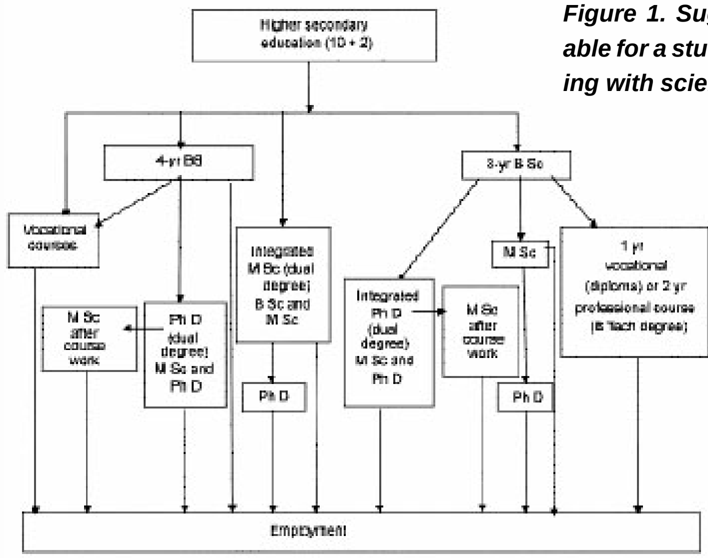

Figure 1. Suggested multiple options available for a student coming out of 10+2 schooling with science stream.

7. Admission to Integrated PhD after 3-years of BSc (MSc degree can be given along with the PhD degree).
8. Admission to vocational courses immediately after passing out from school or after Bachelor's degree.

7. Implementation

While it may be desirable to have a uniform pattern of post-school education in the country, it is obvious that given the diversity in the needs of different students and the capabilities of different teaching institutions, a uniform pattern would fail to deliver the qualities of graduates required in different fields. Therefore, the different programmes suggested above may continue, for the time being, in parallel.

Some General Suggestions in This Regard are as Follows:

The suggested 4-year BS programme must be introduced initially at only those institutions which have good ongoing research, PG and UG teaching programmes so that they can develop a good academic programme without major hurdles.

The large number of ill-equipped colleges spread across the length and breadth of India would find it difficult at this stage to implement the 4-year BS programme and to deliver the required level of excellence. Therefore, the 3-year BSc programmes with reorganized broad-based curriculum, should continue at these institutions. The better endowed university departments should take a collective responsibility to provide opportunities of higher learning to the students graduating from such colleges. While some of these institutions may continue or initiate integrated MSc-PhD programmes for the 3-year BSc graduates, others may continue with separate MSc and PhD programmes, as existing. However, the 4-year BS programme may be introduced at all institutions over the next 10 years.

The 4-year programme will be at variance with the present minimal requirement of MSc qualification (five years post +2 school level) for most governmental and university teaching positions as well as scientific positions in various organizations like DAE, CSIR, DRDO, ICMR, ICAR, ISRO, etc. This would raise the question of equivalence of these degrees for employment. It is expected, however, that a provision for exit after the course work from the dual-degree PhD programme with an MSc degree should provide an opportunity to those who seek employment with an MSc degree rather than after the PhD degree.

Necessity for Teachers' Training and Better Pedagogy

It is obvious that any learning programme depends heavily on the understanding of the teacher and methods of teaching. With continuing rapid advances in different fields of Science, it becomes essential that the teachers not only keep themselves abreast with these developments but also be able to excite young minds so that they become more imaginative and creative. In addition to the need for self-learning by teachers, there is a need for organized training to update their knowledge, understanding and application of newer developments.

A major limitation of teaching of science in our universities/colleges is the general absence of even basic laboratory exercises. To reverse this situation it is necessary not only to allocate enough time for laboratory work but also to improve the facilities and to design and develop simple experiments (including open-ended ones which stimulate analysis and thinking on the part of students) which are doable even in remotely located colleges, etc.

8. Concluding Remarks

Much of our current education system seems to be contrary to the basic philosophy of education that teaching is not a process of filling an "empty vessel" with information and that the learners are not passive recipients of "ready to use" packages of information. Education or teaching is a bidirectional interaction between the teacher and the learner.

The great philosopher and statesman Sarvepalli Radhakrishnan stated "to help the students to earn a living is one of the functions of education, *earthakari ca vidya*". However, he further says "Education, according to the Indian tradition, is not merely a means of earning a living … . It is initiation into the life of spirit, a training of human soul in the pursuit of truth and the practice of virtue … all education is, on the one side, a search for truth; on the other side, it is pursuit of social betterment". Therefore, he commends "Education should give the children not only intellectual stimulation but a purpose" and "any satisfactory system of education should … . insist on both knowledge and wisdom, *Jnanam vijnana-sahitam*. It should not only train the intellect but bring grace into the heart of man".

Shri Aurobindo highlighted three basic principles of the teaching-learning process:

1. Nothing can be taught – the teacher is not an instructor or task-master, he is a helper and a guide;
2. The mind has to be consulted in its own growth – the idea of hammering the child into the shape desired by the parent or the teacher is barbarous and ignorant superstition;
3. The teacher should work from the near to the far, from that which is to that which shall be.

We need to follow these basic tenets of education. Only then will our new generations of students graduate out of their learning institutions full of knowledge and with the capability to analyse and creatively use that knowledge.