Undergraduate science education in India: possible remedies to an old problem?

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The sad state of affairs in undergraduate science education in India is a topic much talked about. I present here a set of constructive and concrete suggestions that can remove the existing ills while adding value to the science undergraduate degree. A three-pronged approach, covering practicals, lectures and projects has been suggested with as much detail as possible. The Chemistry (Honours) course at the University of Delhi has been used as a model system for citing specific examples.

It is rather strange to note that in spite of several essays/talks on science education in Indian universities doing the rounds, the student input is very much missing. This is not because the students do not realize the ills of the system, but perhaps because of the fact that students, largely, are either too concerned with developing their 'career' (whether in science or elsewhere) or have become rather apathetic over the years, due to prolonged exposure to a rather rigid system. I, therefore, feel it is essential to consider the student perspective on such a vital issue. Instead of taking a negative approach, i.e. focusing on what are the things that are amiss with our kind of science education, I seek to take a fresh look at the available resources and make a set of constructive suggestions which can be implemented hopefully without much difficulty, within the existing set-up.

The undergraduate BSc Honours course in Chemistry at the Delhi University is used here as a model system, because of its relative success, and my own familiarity with it. Since creativity does not stem out of funding alone, academics must develop a fresh, self-sustaining and result-oriented model for the future of Indian science. Melvin Calvin once commented aptly, 'Temporary red brick structures on University campuses are good enough for fifty years or more', and he did his Nobel Prize-winning work in one such building.

Introduction of more vocationally-oriented courses is perhaps not the solution to counter declining student interest (and hence, enrolment) in science courses. Additionally, an undergraduate course in one of the fundamental sciences (physics, chemistry, biology) makes for a firmer grasp of the basics, while allowing considerable flexibility within the course. A good understanding of even somewhat 'unrelated' subjects from other fundamental disciplines, like a physics undergraduate doing a paper in biology (for a year or two), is extremely conducive to the creation of a conceptual framework that later helps in shifting fields, if desired. In the modern era of integrative science when the traditional boundaries between disciplines are almost disappearing, such cross-disciplinary training bodes well for any budding scientist. The science course at Delhi University is not very intensive and it leaves enough room for the students to develop other skills and discover their true interests. This is in pleasant contrast to the more professional courses (e.g. engineering/medicine), where the number of 'burnouts' keeps increasing with the intensity of the courses.

It is therefore essential that the positive features of the Delhi University pattern are retained while incorporating measures that would add real value to the undergraduate science degree from an Indian university. I will divide the essay into three sections, not necessarily exclusive.

Experiments

I begin with what I consider the most important aspect of undergraduate science education: experiments. Hardly can one overemphasize the importance of experiments in science. It is therefore important to identify the primary components of almost any experiment, which I believe to be the following: design, techniques and interpretation. Unfortunately, writing loads of 'practical reports' (most of the times, copying them from others!) does little to teach one any of the following aspects of experimental science. The total number of practical sessions in the whole year should be divided into roughly equal sessions for design, techniques and interpretation. In the design sessions, a few theoretical components from the current topics being taught should be dealt with. After an introductory didactic session (may be half an hour) covering an overview of the classic experiments in the topic; the class should be divided in groups of three/four, each group being given a specific problem to look at. At the end of the session, each group presents and discusses its design with the instructors. The sessions on techniques would be more like what is usually done in the name of 'practicals' in the existing set-up. There can be a set of sessions covering specific techniques (specific examples from a chemistry undergraduate course would include topics such as volumetric analysis, polarimetry, spectrophotometry, pH-metry, organic compound detection, etc.).

Data interpretation and statistical analysis are immensely important aspects of the whole gamut of experimental sciences. These can be conducted in lines of the experimental design sessions, with a short didactic section preceding the distribution of various sets of results (from experiments on one topic) in the class for analysis. The reduction of more conventional practical classes where students mostly repeat age-old experiments, is also a constructive solution to problems posed by resource crunches and strikes by laboratory staff. To ensure serious involvement of students at these sessions, it is beneficial to take a cue from the IIT system, where every practical session is graded. The year-long aggregate of practical class scores should contribute to fifty per cent of the total marks of the practical component of the examination (which normally accounts for one-third of the total marks of the complete university examination). The other fifty per cent of the marks for the university practical examination should include a written paper (with two sections: experimental design and interpretation of results) and an examination of the techniques (hands-on) judged by external examiners.

It is difficult to imagine a modern undergraduate science course without proper stress on appropriate computer courses. I recommend introduction of a common compulsory paper in computer skills in the first year for all science undergraduate courses. It is necessary that every science undergraduate at the end of the first year should be familiar at least with the following skills.

(1) Doing literature searches on the web (can be taught in a classroom session with one computer, if resources prevent one from allotting one computer per person in the class).
(2) Writing reports (e.g. using MS Word), preparing presentations (e.g. MS PowerPoint), drawing up tables, graphs, etc.
(3) Writing basic algorithms and simple programs (if possible) in simple computer languages like QBASIC or/and MATLAB. More efficient programming languages can be taught, provided the resources exist.

Theory

The next issue in focus is organization of the classical teaching sessions. This is an area that particularly needs to be worked upon at two different levels. I will first describe the role of the university administration. The inherent dynamism of the sciences necessitates that there is a different procedure (simpler and quicker) for accommodating changes in the syllabus than those prevalent for the arts and the humanities.

It is vital that the course is not overloaded with textual information. I therefore suggest the following distribution of 'theory papers' over the three-year span of the course (Table 1). Specific examples from the chemistry (honours) course are provided in brackets alongside.

The non-honours courses can be common to all students from other disciplines. In effect, this means that each faculty runs two sets of lectures, one catering to its honours course students and another for students from all other disciplines. This should prove to be more efficient for the individual faculties, as this would do away with sparsely attended lectures for individual groups of students who are not doing the subject for their honours course.

With every science course, it is not very difficult to identify areas that require a primarily factual input *vis-à-vis* those that require more conceptual framework. Once identified, the conceptual areas might be emphasized more by organizing weekly 'questions and problems' sessions. A couple of hours per week (in all) through the year should prove to be of immense benefit to the students. If the various lecturers stagger their schedules in a manner that at any point in time there are no more than two sets of 'heavy-concept' topics being discussed, these 'mass supervision' sessions can prove to be of much help. Not only will this aid the understanding of the topic, these informal sessions might ignite further interest in the topic. The annual university examinations should adequately reflect this conceptual thrust of the course (as opposed to the factual overload).

No matter how updated the syllabus is, it can never reflect the cutting edge of science research, which necessitates a definite degree of freedom to incorporate as much current science as possible. To achieve this, a part of the theoretical assessment should be made internal. A possible method to do this efficiently is suggested below. The students are divided into groups of six/seven in the beginning of the term and assigned a set (may be two/three) of original research papers/reviews on a current topic relevant to the syllabus. At the end of the term, each group is asked to make a verbal and a poster presentation on the set of papers. These presentations could be internally evaluated, and two presentations in the whole year (no presentation should be assigned for the final term) could contribute to twenty per cent of the full marks for the theory papers. This would not only develop vital skills of reading current research literature, it would also give them the experience of preparing and making presentations, posters, etc., an absolute requirement for anyone who pursues science as a career.

Research projects

Research is the only way of doing science. Unfortunately, it is largely missing from the undergraduate science curricula at present. While other aspects of the course (e.g. group presentations on current research topics every term, experimental design sessions in the practical classes) should hopefully contribute to a critical appreciation of research-based science, it is of much benefit if the students are exposed to hands-on research as early as possible. To do this, without imposing more curricular load on the students, first- and second-year undergraduates should be encouraged to do short projects during their vacations. These might be based in the college, and should preferably provide a value addition for the college [e.g. synthesizing a costly chemical for future use from relatively cheap precursors], or might rely on the student's own initiative. The students must also be regularly informed about the vacation project schemes run by funding institutes like the Indian Academy of Sciences, Bangalore, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, etc. These projects should not be evaluated for purpose of the degree.

However, there should be an option in the final year of the course [for those

Table 1. Schematic structure for organization of theory papers through the course

First year
• Two papers from the honours course [1. Inorganic and physical chemistry; 2. Organic and physical chemistry]
• Any *two* of the other three basic sciences [mathematics, physics, biology]
• Computer skills [common to all science courses]
Second year
• Three papers from the honours course [1. Inorganic; 2. Organic; 3. Physical]
• Any *one* of the three basic sciences at an advanced level
Third year
• Three papers from the honours course

who have perhaps discovered their penchant for serious research] for students to do a dissertation project, instead of the usual set of practical classes. This project should ideally last for two full terms and the dissertation should take place in the final term, in the presence of internal and external examiners. The set of available projects can be drawn up from within the faculty or/and from outside [e.g. nearby national laboratories, industry R&D departments, etc.]. In case the student chooses his/her own supervisor, he/she should get his project topic ratified by the faculty beforehand.

The normal set of practical sessions [design, techniques, interpretation] should be an available option for those who do not want to take up the dissertation project.

All said and done, it is enthusiasm that counts the most. To build it up from the very beginning of the three-year course, it is important that new first-year students are exposed to successful professionals who have done the course. An early exposure to successful professionals (be it lecturers, scientists or businessmen!) who have passed through the same course at some point, helps build-up confidence in the students, thereby preventing/reducing the usual 'attrition rate' to more professionally lucrative pastures. Instead of mourning the loss of truly interested students in science undergraduate courses, I feel it is time we set about making the appropriate positive changes within the available resources.

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