First-Year Chemistry In Two Countries Oceans Apart: United States of America And India

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Chemistry is the central science that provides important understanding of our world and how it works. With its countless contributions in our daily lives, it is an important area to focus in this era of science and technology. It is a discipline that develops around and reflects social, economic, and technological changes. First- year chemistry serves as the introduction to knowledge, techniques and scientific critical thinking skills for students pursuing careers in chemistry related fields.

Technology has made it a very small world. In today's world, chemistry is a global enterprise drawing from international expertise to address and solve industrial, environmental, and health problems with far- reaching consequences. Students of chemistry in this fast changing world, must be exposed to and be aware of the global framework of science. First- year chemistry curriculum is of vital importance in this preparation process. Educators in the business of this entry level chemistry face tough challenges in the years to come in order to maintain competitiveness among the talented students worldwide.

United States of America and India, two countries oceans apart, are two major players in the advancement of science and technology. United States of America, with a wide array of public and private institutions, is still one of best in the world in higher education. Faculty rosters at various American universities are studded with so many Noble Prize winning chemists. Convergence of technology has allowed India and China, world's two biggest nations a huge stake in the success of globalization. In Asia, they are the leaders in the scientific world. In a recent documentary, British Broadcast Corporation (BBC) describes India as the “emerging Asian tiger” exporting science and technology all over the world. A large English speaking population helps India to be an active and major partner in the scientific community. The education system in India must be conducive to creating science literate workforce for the country. Exchange of ideas between educators around the world often helps to develop best teaching practices. International collaborations bring together chemists from diverse academic, cultural and ethnic backgrounds. A close look at the similarities and differences in chemical education in these two countries may help academic institutions decide what to adopt and what to avoid in a first- year chemistry classroom. This comparison may help educators develop a curriculum satisfying socio-economic need of the community in accordance with resources available.

I have been teaching first year or freshman level of chemistry at Houston Community College for the past eighteen years. It has been an exciting and challenging journey for me. Houston Community College System (HCCS) is the second largest singularly accredited community college in US with an enrollment over 50,000 students. HCCS is a multi-campus institution providing educational opportunities in and around this large Texas city of over 2 million people. With an open admission policy, HCCS is noteworthy for the diverse nature of its student population with a significant number of international students. All our chemistry courses have transfer credits to major four-year

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institutions. Prior to joining HCCS, I gathered a different perspective towards first- year chemistry as a graduate teaching assistant in the U.S. at a large public institution as well as at a private institution with a fairly small student population.

My encounter with chemical education in India was as an undergraduate student majoring in chemistry at an Indian university recognized for its excellence in training and path breaking research in science, engineering, and arts. It is located in Calcutta, which had been the capital of British India for a long time. The university has been declared as the Center of Excellence by the University Grant Commission (UGC) of India and has been rated with a five star status by the National Assessment and Accreditation Committee of India.

It is common knowledge that instructional methods and curricula vary from one institution to other in different parts of the same country. From my first hand experience in first-year chemistry in both countries, following is a list of contributing factors shaping chemical education in these two systems. This is entirely from my knowledge and observations, as a chemistry faculty as well as student. This is open to discussions, recommendations, and additions from others experienced in the field.

First-Year Chemistry Course Content

The structure of university chemistry curricula in the U.S. represents a horizontal arrangement of courses from different areas of chemistry with successive four years of undergraduate study. First or freshman year deals with general chemistry. Second or sophomore year is devoted to organic chemistry. Physical chemistry is the focus in the third or junior year of study. Fourth or senior year is for upper- level or special topics courses in inorganic/analytical/biochemistry, many of which carry graduate credits towards a masters or doctorate degree. At many institutions, senior year provides an opportunity for students to participate in undergraduate research which compliments the leaning process.
First- year chemistry in the U.S. is offered under several titles such as: General Chemistry
Introductory Chemistry
College Chemistry
General, Organic, and Biochemistry
General, Organic, and Biological Chemistry
Since this freshman level chemistry course is offered to students with a wide variety of majors, it is a unique mixture of inorganic, organic, and physical chemistry with very little emphasis on analytical chemistry. A typical general chemistry syllabus will include the following topics from the three areas of chemistry over a period of two semesters or an academic year:

Inorganic Chemistry : Chemical Formulas and Composition, Chemical Equation and Stoichiometry, Types of Chemical Reactions, Chemical Bonding and Molecular Geometry, Chemical Periodicity, Reactions in Aqueous Solutions, Acids, Bases, and Salts, Ionic Equilibria, Solubility Product Principle, Metals, Nonmetals, and Metalloids, Transition Metals and Coordination Compounds, Nuclear Chemistry

Physical Chemistry: Quantum Theory and Electronic Structure of Atoms, Gases and Kinetic Molecular Theory, Chemical Thermodynamics, Chemical Kinetics, Chemical equilibrium, Buffers and Titration Curves, Electrochemistry

Organic Chemistry: Functional Groups and IUPAC Nomenclature, Fundamental Classes of Organic Reactions, Natural and Synthetic Organic Compounds

Introductory and college chemistry are primarily for students in allied health science majors. These two freshman

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courses devote about half of the syllabus to organic chemistry and biochemistry including topics like carbohydrates, lipids, proteins, enzymes, vitamins, and hormones among others. First- year chemistry is often a core curriculum requirement for most degree program in the U.S. It exposes students to all areas of chemistry in a nut shell.
In India, the undergraduate study is a three year program just like the EuroBachelor program, expandable to four years in some areas and if necessary. The structure of chemical education is vertical where students study organic, inorganic, and physical chemistry concurrently throughout their three years of undergraduate program. There is no such a class or course as general chemistry or introductory chemistry in India. Fewer topics from the three areas of chemistry are covered in the first year. That allows topics to be covered at a slower pace in details with great emphasis on derivation of difficult concepts. Often, this allows students to absorb and retain difficult theories in chemistry better. A limited number of newer academic institutions like the Indian Institute of Technology at Kanpur offer a general chemistry course in the first year to non majors requiring substantial background in chemistry to complete their training.

First-Year Chemistry Student Demographics

A first- year chemistry class in the U.S. is filled with a very diverse student population. This entry level chemistry in most institutions is a core curriculum requirement to be fulfilled in a degree plan. As a result, students majoring in science and engineering, liberal arts and humanities, fine arts, nursing and allied health sciences as well as pre-medical students, all register for this class for the required credit hours in natural science. Some students have genuine aptitude towards science and would like to pursue careers in scientific fields. For others, this class is like a sliding door in the pathway of the degree plan. There are very young students fresh out of high schools with excellent science background along with many first generation college students with no prior exposure to chemistry. In junior colleges and

community colleges this class often includes a large number of matured students on job training program. This is due to the downsizing of many industries and out sourcing of many local jobs abroad. In recent years, most academic institutions in the U.S. have been offering chemistry, especially the lecture portion of the course, as a distance education course on-line. This enables fulltime working- students of all ages to enroll in first-year chemistry courses. Diversity in academic background, age, and ethnicity make a first-year chemistry class truly heterogeneous. It is a difficult task for the instructor to set the optimum pace for the delivery of instruction to challenge and stimulate the bright minds without overwhelming the students new to science and mathematics.

An Indian first-year chemistry class is much more homogeneous in terms student background. In the last two years of high school (11 th and 12 th grade) students are channelized in four major streams of study based upon aptitude:

Science
Liberal Arts and Humanities
Fine Arts
Business and Commerce

This is the general trend which may vary slightly from state to state since high school education in India is under the State Education Board. There are very few high school systems under the Federal or Central Education Board.

India is a country of over a billion people which creates tough competition for young people in the academic world as well as in the employment arena. Chemistry offers wide spectrum of career fields with national and international corporations in public and private sectors specializing in medicinal chemistry, forensic chemistry, environmental chemistry, food chemistry, materials and technology, and chemical education. Employment opportunities serve as the driving force behind the selection of science stream in high school and chemistry as major at the university level for many talented and bright students.

In the last two years of high school, the science stream provides students with a good exposure to physics, chemistry, and mathematics. After graduating from high schools, they continue to study in their respective areas of specialization. In India, medical school starts right after high school with very difficult admission tests used for the selection criteria. Medical students attend college level chemistry classes under the medical schools. Same rules apply for most

engineering and pharmacy schools. First-year chemistry in India attracts primarily science majors (physical and biological sciences) and engineering majors at different IIT (Indian Institute of Technology) locations who are totally committed upon the start of their university study.

There is no age bar for admission to a first- year chemistry class at an Indian university or college. There are very few evening classes. Most classes require in- person meetings and extended laboratory hours. This makes it very difficult for people with full-time jobs to enroll in the undergraduate program. Recently, some universities have started an "open university" system with flexible schedules to attract working students to the undergraduate program. There needs to be more data to comment on the success of such newer approaches to higher education. The masters and doctorate program generally have more of working professionals. This makes a first-year chemistry class primarily for young students fresh of high school. There is a common thread that ties the first-year chemistry students in India and makes it easier for the educators to set the ideal and optimum standard of instruction.

Instructional Methodology and Aids

Chemistry involves difficult qualitative as well as quantitative concepts. It is the responsibility of the instructor to successfully demonstrate that the underlying principles and ideas in chemistry are very simple. This in turn helps to bridge the concept-context gap for students and enhance public understanding for the science. Instructional delivery plays an important role in making the subject matter clear. Teaching strategies that address different learning modes (auditory, visual, kinetic, and olfactory) create an atmosphere conducive to learning especially in a class of students with diverse academic backgrounds and goals. A difficult concept in chemistry can be better conquered by an innovative teaching approach using multi-media teaching aids. Each student has a unique way of learning and technology helps teachers cater to that.

First-year chemistry classrooms in the U.S. have experienced an explosion of technology during the last decade. Lecture rooms and auditoriums are equipped with Internet ready computers, sophisticated projection systems, electronic as well as traditional black or white boards. Instructors have a choice of traditional lecture using board and marker, overhead projectors with acetate transparencies, PowerPoint slides from CDs on a computer, or animation of

chemical processes on a video player. There can be a balanced mix of these different teaching aids to satisfy the individual learning needs of students across the room. In many state universities (public schools), a freshman chemistry class can accommodate up to 200/250 students in an auditorium. Standard practice of lecture using the board can be very demanding for the teacher and not helpful for the students in the back rows.

Effective implementation of technology can greatly enhance the learning experience under such circumstances. Downside of this includes presentation of a vast amount of difficult subject matter in a very short time. Students often can not keep up with the pace of a PowerPoint slide show filled with chemical equations and graphs. To compensate for that, many instructors have created on-line resource sites specific for their courses using WebCT, Black Board, Page Out among others as delivery platforms. Students can find course specific lecture notes, homework, test reviews, practice tests and related links at these sites. These are helpful learning tools that offer flexibility in reinforcement of difficult and essential concepts in a content-heavy chemistry course.

In India, an average first-year chemistry class consists of about 75/100 students. A few state of the art modern universities with resources implement technology in instructional delivery. In most places, traditional lecture with blackboard is still the main mode of instruction. It definitely provides a reasonable pace for science and engineering students to keep up with, absorb, and retain the subject matter. But it does not make thermochemistry or kinetics as appealing as a bright, colorful PowerPoint slide where reactants collide, go over the activation energy hill, and slide down to products. When a visual learner sees hydrogen molecule being adsorbed on a catalyst surface which in turn adds to the same side of a pi bond from an alkene or alkyne leading to a syn addition product, that image will be retained for a long period of time. Computer is not the key to solving problems with teaching and learning chemistry, but advanced and sophisticated computer graphics can surely help students in understanding chemistry in a more visual and enjoyable way.

Annual or semiannual evaluation of instructors by the students is a common tool used by most universities in the U.S. to maintain institutional effectiveness. This is an excellent way for the teachers to get open and unbiased opinions from

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the students about their instruction. Positive as well as negative criticisms from the students turn out to be very constructive for educators in modifying and improving their individual teaching techniques.

Every semester, freshman students have a choice of sections for the same general or college chemistry course being offered by the university by various instructors at different time of day and night. Where education is a very expensive business, on-line rating of instruction on faculty members definitely helps students to narrow their search and be a smart shopper during registration and enrollment period.

According to my knowledge, no such practice of evaluation of instructional methods by the students, are in place in the Indian university education system. This might be a nice addition to maintain consistency and effectiveness in teaching standards. This may also work as an incentive for teachers to keep current with various professional developments.

Testing Methods

Most universities and colleges in the U.S. operate on a semester system which includes fall, spring, and summer semesters. Some institutions are on a quarter system which moves faster. In recent years, mini sessions are offered during the winter breaks catering to students with heavy workloads during regular academic sessions. Testing is conducted through out the semester with a cumulative semester final in most cases. Because of the large size of freshman classes, multiple-choice tests are offered all across the country. Multiple-choice is the nature of testing in the U.S. for most standardized tests like SAT, PCAT, MCAT, DAT, GRE among others. Scantron tests make it easy for the graduate teaching assistants who are generally responsible for grading these tests. Private schools, junior and community colleges where class size is smaller, instructors often devote a small section of the test to partial credit (show you work) questions. Proponents of multiple choice testing would point out that this helps students to focus on the highlights of concepts and apply them effectively rather than being burdened by the long derivations of different theories and formulas. Guesswork and probability can help a student earn a passing grade without much appreciation or understanding for the subject matter.

Indian university education is divided between annual and semester systems. Testing is less frequent than in the U.S. Most institutions have a cumulative final exam at the end of an academic year or semester. Smaller class sizes, course content, and delivery techniques allow the tests to be made primarily with partial credit questions with emphasis on derivation of theories and formulas which involves considerable amount of writing. There are no teaching assistants in

most Indian universities. Hence grading is demanding for the instructors.
Testing and teaching methods may explain the general observation that chemistry students in the U.S. are more efficient in application of concepts rather than derivation, while the opposite is true in India.

Laboratory Experience

Chemistry is an experimental science and laboratory experience is an integral part of learning chemistry. First-year chemistry laboratory curriculum is pretty similar in both countries. It involves predominantly wet chemistry with experiments from inorganic and physical chemistry along with some simple organic synthesis like the preparation of an ester. Very little instrumentation is applied in a freshman chemistry lab. Some universities and colleges in the U.S. offer honors sections for first-year chemistry geared towards accelerated students to pursue in-depth, analytical work in the field. These are the students that have some extensive laboratory experience in the first year of undergraduate study. Students have been introduced to computer simulated/assisted laboratory experiments at some institutions in the U.S. This allows rapid collection and graphical display of data particularly helpful in a large class. Simulations can demonstrate experiments which are considered dangerous for students in the freshman level to perform. In general, more rigid safety rules are enforced in a freshman chemistry lab in the U.S. compared to than that in India. It is important to install the importance safety concerns in the minds of chemistry students from the very beginning since chemists have a special responsibility to enhance the condition of the environment and help advance human health.

Textbooks

In this technology driven twenty first century, authors and publishing companies have taken a quantum leap in the scientific coverage and pedagogy of first-year chemistry textbooks. Technology offers tools that aid teachers to instruct

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and inspire students to learn. A current textbook comes with support packages for the student as well as the instructor. Such a package normally includes the following:
• Text specific web site where text, problems, and media all are integrated in an unique environment
• PowerPoint lecture presentation for the instructors
• Course ready notes for the students
• Interactive tutorial with testing and quiz
• Electronic homework
• Visual resource library
• Links to university libraries with complete articles from scholarly and popular publications
• Entire text in electronic version
• Student solution manual and study guide in electronic version or in hard copy
• Test bank and course management system for instructors
“Chemistry in Action” section is an integral component in every textbook which gives students a better understanding of the real world perspective of chemistry. History of chemists adds a human touch to the learning process. Colorful pictures with space filling three dimensional representations make great visual appeals to the readers. Such advances in publication come with a huge price tag which is difficult for many students to meet. In order to compensate for that, most publishing companies offer special packages at reduced costs with special options such as paper back binding, black and white prints, electronic version of text, text divided into two parts for two successive semesters for an academic year.
This is a global trend in publishing and Chemistry textbooks in India have taken a similar format. Real life applications, useful web links, and practice problem CDs are part of most freshman chemistry textbooks. Text books from my undergraduate study with countless pages of back and white prints with chemical equations as the only adornments seem to belong to the dinosaur age.
Educators in both countries can extract the best of available tools from a textbook and direct the students to explore ideas and visualize chemistry in a new dimension under an interactive environment.
In conclusion, perhaps this discussion on first-year chemistry will give educators a global perspective that can be helpful in discovering and overcoming barriers to reform in first-year chemistry education. Prize winning posters at

ACS meetings remind us time and time again that it is a chemical world and chemistry is everywhere. Numerous concepts, new vocabulary, avalanche of facts, and overemphasis on mathematics are often at the root of student's fear for chemistry. Treating chemistry as the “human element” with intelligent application of technology in the classroom can best work for motivating students and forward chemistry in the community. After all, chemistry is a discipline that reflects social, technological, and economic changes. In this century, we chemists have to be more creative and dedicated to produce highly educated citizenry that can face the growing global challenges.

CONFCHEM on-line conferences are organized by the ACS Division of Chemical Education's Committee on Computers in Chemical Education (**CCCE**). Send additions or corrections for this page to John H. Penn at John.Penn@mail.wvu.edu

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