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Need to redesign chemistry education in India for the 21st century learning needs

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ABSTRACT

This article focuses on what ails chemistry education in India and how it can be redesigned keeping in view the learning needs of the 21st century and the goals of the New Education Policy (NEP-2020). Special focus is on regular revision of chemistry curriculum in view of rapidly growing chemistry knowledge, adoption of innovative ways of learner-centric teaching, strategic use of technology and scientific approach to assessment based on higher-order thinking skills. It is imperative that to be successful in this revamp, chemistry teachers of the country at all levels are regularly empowered in all aspects of chemistry education. Professional growth of chemistry teachers is a journey and not a destination.

1. Introduction

Chemistry is an exciting field of study which impacts all facets of our life. Chemistry education which is the teaching-learning process of chemistry, is the foundation of chemistry research which plays an important role in the development of a nation. Chemistry education also equips one for a variety of many interesting and rewarding careers and the list of such career possibilities for chemistry professionals is very long and varied. A well-trained chemist always remains in demand anywhere in the world.

2. Present chemistry education and crisis of creativity

Chemistry education in India unfortunately has not changed much with the changing times. It still focuses on examination, rote learning and scoring high marks. Students are examined one against the other. The real ability, achievement or potential of the students is never brought out. The student's mark sheet is the prestige sheet for the family but a pressure sheet for the child. The syllabi are very heavy and outdated thereby creating a big gap between what is learnt and what should be learnt and this ultimately affects the quality of chemistry research. The method of teaching is the traditional teacher-cen`tric talk and chalk method where students are merely passive listeners and which neither engages students nor encourages thinking, innovation and creativity amongst them. The exams are mainly knowledgebased with a focus on lower order thinking skills such as knowledge, understanding and applications. Further excessive dependence on technology of the present-day students has impacted adversely the generation of original ideas, plans and hence creativity. It is therefore not surprising that such an education system has created a crisis of creativity in Indian science [1,9]. It has now been, for example, more than 90 years since C. V. Raman got the Nobel Prize in Physics in 1930, that no other Indian scientist working in India has been able to win a Nobel prize. Not only that, since the second half of the last century India has not been able to reproduce the magic of the early part of that century created by eminent scientists such as Ramanujan, Meghnad Saha, Raman, S. N. Bose and G. N. Ramachandran. India with the third largest scientific and technical manpower in the world also ranks third after China and USA in number of scientific publications. However according to a report, out of the 4000 most cited researchers in science in the world, only 10 (0.25%) are from India. 2020 Global Talent Competitive Index (GTCI), which measures and ranks

countries based on their ability to grow, attract and retain talent, ranks India at 72. All this sounds an alarm bell for science education including chemistry education in India as it is the foundation of all scientific research which is the cornerstone for the development of a nation.

3. 21st Century chemistry education

To understand 21st century chemistry education, one must first of all understand what a 21st century education is not. A 21st century education isn't a class of students sitting quietly in a classroom, taking notes. It's not a teacher-centric approach, teaching students for the examination, telling students what they need to memorise to get 90%+ marks , assuming every student learns in an identical way. A 21st century education is actually much more and different than all this [5].

A 21st century education is one that responds to the economical, technological and societal changes that are taking place at an ever-increasing pace in this complex world which is witnessing Industrial Revolution 4.0. It's an education which shifts focus from examination and rote learning to conceptual clarity, application, problem solving, critical thinking, innovation and creativity in conformity with the goals of New Education Policy (NEP-2020). It's an education that prepares students to face the challenges of life in the 21st century and succeed in all the spheres.

For the 21st century chemistry education, curriculum, teaching methodologies, assessment as well as infrastructure need to be in tune with the times. Students, besides disciplinary, interdisciplinary and practical knowledge of chemistry also need to develop 21st century skills, values and attitudes to acquire competence to thrive in the fast - changing modern world. 21st Century skills include, besides the literacy (viz. information, media and technology) and life skills (viz. flexibility, leadership, initiative, productivity and social) the four 'Learning Skills' viz. creativity, critical thinking, communication and collaboration. These four learning skills are not to be only understood as such but rather they should also be part of every topic in chemistry in the same way as literacy and numeracy are. Only then these skills can be imbibed in our students

4. Growth of chemistry knowledge and chemistry curriculum

Chemistry is the most productive of all branches of science. The result is a very fast growth in chemistry knowledge - so fast that the doubling time of growth of chemistry knowledge has shrunk considerably. Chemists, for example, are continuously producing or making new substances in laboratories. This has led to an exponential growth in the number of chemical substances. This number which was just a few hundred in 1800 is expected to reach 300 million by the year 2050 and 5 billion by the end of this century [3]. Further the number of elements in the periodic table which was just 63 in 1869 has now risen to 118. Not only that, many new concepts, ideas, theories are emerging on the chemistry scene. The result is that many new sub-disciplines of chemistry such as green chemistry, computational chemistry, combinatorial chemistry, chem-informatics, supramolecular chemistry, phytochemistry, food chemistry etc. have emerged over a period of time.

In view of this rapidly growing chemistry knowledge, the chemistry curriculum needs to be revised regularly with a focus on core essentials and kept up to date with the demands of the industry and the modern day-market. At the same time, it also needs to be ensured that the curriculum is light thereby giving students more time for thinking.

5. 21st Century teachers: Innovative methods of chemistry teaching and assessment

Teachers have a very important role to play in imparting 21st century chemistry education. Unfortunately in India, most students continue to be educated in the same way as they were in the past. Traditional teacher-centric methods of teaching make little sense to today's 21st century students who have grown with technology and who learn and think

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differently, and for whom making use of information is far more valuable than simply knowing things [2].

21st century teachers must embrace new learner-centric ways of teaching and learning like flipped classroom model which focus on higher order thinking skills and encourage thinking, innovation and creativity amongst learners. The main idea behind learnercentric education is that learners learn best when they are motivated towards the topic and they, on their own, seek out new knowledge and skills because they need that in order to solve the problems at hand. The flipped classroom model boosts student learning and achievement by reversing the traditional model of a classroom by focusing class time on student's understanding through active and collaborative learning rather than on passive lecture component [10]. Further, besides flipped classroom model, there also needs to be more focus in teachinglearning on case-studies, experiential, collaborative, projectbased and problem-based learning rather than merely lecturebased learning as is the case at present [6,11].

6. Assessment

Further the teachers also need to be trained in transforming the culture of assessment should be competency-based and not merely knowledge-based. Assessment process should be made more scientific to encourage multiple skills of the students [7]. Questions in exams need to be on concepts, critical thinking, analytical thinking and various ways of looking at the avenues of knowledge and not just on speedy reproduction of information. It is important to realise that assessment drives learning. The way we assess our students, the students will learn accordingly That is the best way to slowly draw our students away from rote learning and lead them towards innovation and creativity.

7. Technology in chemistry education

It is difficult to imagine 21st century chemistry education without technology. In this regard, teachers need to become tech savvy and understand their changing roles as mentors or coaches or facilitators rather than merely knowledge providers [4].

Teachers need to upgrade their ICT skills on usage of basic tools like word processing, presentation tools, spreadsheets, graphics, video capture & editing tools, anti-plagiarism tools, learning management systemsetc. Learning Management System (LMS) empowers a teacher to create a virtual classroom in which all the e-resources like videos, pdfs, ppts, word docs, link to other resources, quizzes of various forms, assignments and discussion forums can be provided to learner in a structured manner which can be accessed by the learner in 24 x 7 mode. The teacher can look into the analytics of the LMS and track the learner's self-learning. Assessment through LMS can be used for formative assessments in which multiple assessment methods along with rubrics can be provided to the learner. Timely feedback and quick result analysis can be done which is time-consuming, if done manually.

Chemistry software for structure drawing, 3D visualisation, molecular modelling, in-silico reactions, drug designing, etc. need to be integrated in the teaching methodology as well a part of curriculum to prepare the future chemists.

Chemistry is mainly an experimental science. e-Labs as video demonstrations and virtual labs with simulations need to be integrated along with hands-on experiments for better understanding and visualisation of what is happening inside the reaction flask or apparatus! Manual graph plotting should be replaced by excel or other graph plotters through which one experiment can be understood in a variety of ways by changing the variables in excel rather than performing the experiment just once as is the usual practice. Practical Record books can be in fully ICT mode. Real time observations and inputs of various data in experiment can be taken using ICT Tools and calculations can be automated. Integrating use of ICT tools usage in experiments is also environmental friendly and greener.

With the popularity of online education and coming up of digital universities in India in the near future, teachers also need to become proficient in development of e-content in four quadrant format and MOOCs/Online courses [8].

Conclusion

Chemistry education in India needs to be thoroughly redesigned keeping in view the needs and goals of the 21st century. We need to have modern but light syllabi, embrace innovative learner-centric pedagogies to improve students' learning and shift the focus of examination to assessing their competence (knowledge,

skills, values, attitudes etc.) rather than merely knowledge. This redesigning of chemistry education is possible only if the chemistry teachers at all levels are regularly empowered in each aspect of chemistry education including strategic use of technology. ARPIT (Annual Refresher Programme in Teaching) programmes in chemistry developed by the National Resource Centres (NRC) of Chemistry of the Govt. of India and offered through SWAYAM portal are proving to be a big breakthrough in this direction and are helping in enhancing the competence of chemistry teachers. One needs to keep it in mind that the quality of an educational system cannot exceed the quality of its teachers and therefore the empowerment of the chemistry teachers through their regular professional development is the need of the hour.

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