



Transformative Dimensions of Chemical Education in Rural India: Challenges and the NEP 2020 Roadmap

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ABSTRACT:

The NEP (National Education Policy) 2020 is intended to radically change rural development through major educational reforms. At present, Indian education suffers from several problems including a serious shortage of physical schools, resources and teachers; and a general negative perception towards education. A further difficulty in addressing the problems that exist within Indian education relates specifically to the subject matter being taught. For instance, learning about the theory of chemistry cannot be effectively undertaken unless appropriate laboratories are available as part of the school system even though they do not yet exist throughout India. In order to change the current state of education in India both the construction of adequate physical facilities for regular schools as well as a concerted effort to educate all citizens on why it is important to educate oneself are necessary and the time has come now for the use of technology in place of the traditional method whereby students only learned passively via lecture at their teachers' teaching. Thus, according to the NEP 2020, it is necessary to develop skills that will be of crucial importance to the youth in India over the next years and can only be developed through collaboration between federal and state governments in order to realize a productive future for the children of India.

Keywords: NEP 2020, Rural India, Educational Reform, Chemical Education, Challenges, Pedagogical Shift

1. INTRODUCTION

Education is seen to be one of the main national priorities considered to be fundamental to future development. While the government is trying to make education accessible for all people, there is a significant disparity in literacy rates between urban areas (87.7%) and rural areas (73.5%). Furthermore, even with India's rapid growth, rural areas are significantly hindered from growing due to high population densities and pressure on resources. Rural education must be improved in order to improve quality of life and achieve true national progress through the transformations of the 600,000 villages located in the country. Since most of India's youthful population lives geographically in rural areas, universal education is essential for continued economic growth. Given the fact that India has a much younger population as compared to China or Japan, the country is facing a developmental crisis in that rural learners live with significantly higher incidences of poverty and mortality, and are not receiving access to innovative mechanisms for modern education. If rural areas are not prioritized in the delivery of educational resources as opposed to the urban-focused delivery, India will continue to waste its significant demographic advantage.



India is becoming a significant player in today's global economy, but the ongoing progress of the nation is unbalanced with respect to development, particularly in rural areas. Although cities appear to be bursting with new opportunities and economic growth, two-thirds of the population remains unable to benefit from this increased level of prosperity. Conditions such as agriculture, infrastructure and social services are also lagging considerably behind in relatively remote areas, resulting in a significant difference in the overall quality of life between urban and rural areas. Closing the significant educational gap between urban and rural areas is critical to ensuring that the benefits of development reach every part of India.

Rural students have incredible amounts of potential creativity; however, their learning tends to be based on passive memorization of isolated facts and pieces of information, which inhibits their ability to think outside the box. To help them tap into their ability to think creatively, they need the proper guidance and support. Rural teachers are the most important contributors to unlocking this potential, as primarily through them will students gain the foundation for their education. Additionally, these teachers play an essential role in establishing community relationships. Thus connections are built between students and their families that extend learning beyond the walls of the classroom.

Modern technology is fundamentally based on Chemistry which lays the foundation for Engineering, Medical, and Applied Science careers. For children that reside in rural areas Chemistry tends to be the "least preferred" of the subjects offered because it is typically a very experimental and complex subject; therefore this article tends to focus on the development of the practical aspect of Chemistry education which forms a solid basis for designing a good understanding of Chemistry in the rural environment. The NEP-2020 is a major step forward for this purpose as it attempts to work with the issues that rural chemistry educators face as well as to bring closure on the educational gap within the education system in India.

2. LITERATURE REVIEW

This literature review focuses on prior research, academic articles, and policy frameworks regarding the influence of NEP 2020 on chemical education at both school and higher education tiers. This chapter attempts to emphasize the principal themes, like curriculum, pedagogy, technology, and structural challenges, highlighting the areas of research.

In India, a vibrant and productive scientific and industrial heritage is based on the core theoretical and practical principles of chemistry. The field of chemistry is contributing to the remarkable advancements occurring in India in the areas of pharmaceuticals, agriculture, materials chemistry and sustainability. In the past several years, India has emerged as one of the leading countries in the world for both chemical research and industry and currently accounts for a significant percentage of all research activity in India. At the same time, despite the progress at the highest levels of research, there has historically been much criticism of chemistry education in schools and colleges in India due to the nature of learning to achieve competence in chemistry being almost entirely depended on rote learning, the separation of academic disciplines, and the orientation being based purely on theory. This traditional method of teaching chemistry does not support the development of the critical and innovative thinking skills necessary for successful scientific research. (Krishnan, Brakaspathy & Arunan, 2016)

Recent empirical research indicates serious concerns about possible "dilution" of scientific rigor. A study done by Haque and Amin (2023) found a significant decline in the number of students who chose Chemistry as a core subject following the NEP 2020 policy in general degree colleges across West Bengal. Because Chemistry is generally thought of as a difficult course requiring strong mathematical foundations and large amounts of laboratory work, students taking advantage of the new academic flexibility provided by the NEP have tended to drop chemistry in favor of combinations that they view as easier to complete. Educators are warning that extensive integration of chemistry into unrelated subjects may undermine the depth of knowledge that is necessary to develop a mastery of complex chemical concepts. If this trend continues (from "core to optional"), some researchers predict that there will be significant problems with the pipeline of specialized chemical researchers and skilled chemical professionals in India's economy (Verma, 2024).



The National Education Policy (NEP 2020) was developed by the Government of India to cop up with the changing needs of the 21st century knowledge system. It is a significant move from India's traditional system of 10 + 2 to a new system of 5 + 3 + 3 + 4. In NEP 2020, the idea of holistic, multi-disciplinary, and experiential learning was introduced. Along with the Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), NEP 2020 also affirms that higher education institutions will provide a multi-disciplinary type experience. According to Aithal and Aithal (2020), allowing chemistry students to study and take courses in other subjects, such as environmental policy, economics, and computer science, will result in students being better equipped to address complex global issues that involve multiple disciplines, such as climate change, green energy development, and sustainable manufacturing.

A fundamental change in the way that education is approached can be seen in NEP 2020's push towards experiential/inquiry/discovery based approaches, rather than purely didactic/lecture based approaches to instruction. As outlined in Senapati et al. (2022), the emphasis placed on play/activity-based learning during the early years, followed by experiential learning experiences during the middle and high school years, can serve to change chemistry into a subject of interest rather than one of fear and abstract thought.

The national chemical science education and research under the new policies established by Indian Government (NEP 2020) are examined by Senapati et al. (2022). They note that the chemical industry is the largest sector of the Indian economy, accounting for just over 20% of all scientific doctoral degrees in India. Additionally, the researchers discussed current growth trends, as well as the quality of research being done in India and its overall effect. They demonstrate systemic barriers and document opportunities through the NEP which can be used to advance pedagogical improvement and maximize the ability to do research on behalf of India.

Chand and Dayal (2022) studied the effect model-based instructions had on the learning of Chemistry students in New Zealand, who were in Year 12, and were learning about ionic and metallic bonding. The research used graphical representation of sub-macroscopic structures to provide visual aids and drawings to assist students in understanding the theoretical material covered in their pre-tests and posse-tests. The researchers noted that even using visual representations of the sub-microscopical representations of bonding alone were not adequate to help many students, particularly those who were not native English speakers, retain their understanding of abstract concepts, particularly in relation to metallic bonding. The researchers determined that the use of concrete representations of models is necessary to counteract any misconceptions that exist.

The qualitative study conducted by Nkurunziza and Mugabo (2025) 'The use of improvised chemicals and materials in teaching and learning chemistry in two selected districts of Rwanda' focuses on utilizing improvised materials to teach Chemistry in Rwandan schools that have limited resources, such as using ash or lemon juice as lab equipment. Because of the shortage of materials and large class sizes, practicals cannot be done, but improvised materials allow students to participate more in class. The recommendations made by the authors include providing teachers with training specific to this teaching approach and providing additional resources to help close the gap between theory and practice.

'Innovative approaches in chemistry education for talent cultivation' studied by Chhangani and Gupta (2023) in Udaipur, Rajasthan shows how teachers could incorporate new pedagogy into the classroom to prepare learners for a changing world, both in industry and as a result of student-related changes. By bringing new ideas into the classroom on a continuous basis and modifying the content used for instruction, teachers will be able to provide students with a greater capacity to adapt to the rapidly changing environment. The results of this study demonstrate that chemical teachers must continue to modify their pedagogical practice to develop the required skillset for developing talent in today's workforce.

The academic literature has also addressed the implementation of problem-based learning (PBL) and cooperative learning strategies as methods for assisting students in developing their higher order thinking (HOT) skills. An example of this kind of curriculum can be found in the Central Board of Secondary Education's (CBSE, 2023) curriculum framework for chemistry at the high school level.



While this is an exciting time for educational reform, transitioning towards competencies-based education is not without its challenges. Specifically, teaching complexity (e.g., organic reaction mechanisms, quantum mechanical model of atoms, and stereochemistry) necessitates an adequate theoretical foundation that is not able to be acquired through generalized engagement in activities (Mammino, 2021). Therefore, it is imperative that educators find a balance between providing quality theoretical instruction and providing opportunities for students to apply and practice developing their higher order thinking (HOT) skills through skills-based practice so that all learners can experience an understanding of the molecular behaviour of matter.

The experimental domain of chemical education is the most important part of the chemistry education. Based on the hands-on and competency-based methods that NEP 2020 establishes, the laboratory infrastructure for schools, colleges, and universities must be functional and accessible. Although premium institutions like IITs and IISERs are capable of supporting on-going Advanced Experiential Learning experiences (AEL), Senapati et al. (2022) have remarked that most of the rural and state-funded schools and colleges do not possess the basic infrastructure necessary for conducting laboratory experiments, in addition to the fact that they do not have access to safe chemicals or equipment needed for conducting experiments.

The use of computers and information and communication technology (ICT) in classrooms is a major component of NEP 2020 and will be an important mechanism for providing equal access to high quality education. The COVID-19 pandemic was a catalyst for the acceleration of using digital tools in chemistry courses. Students are able to visualize abstract, dynamic concepts that are generally difficult to visualize using a traditional 2D chalkboard, through the use of 3D molecular modeling, virtual labs, and augmented reality, for example, when trying to understand concepts like bond formation, heterolytic fission, and reaction mechanisms (Iyamuremye et al., 2022). Government-sponsored virtual laboratories through programs such as the DIKSHA platform of the Ministry of Education, as well as the Amrita Virtual Lab project, permit students to conduct virtual laboratory experiments simulating highly dangerous, toxic, or resource-intensive chemical reactions in a safe, inexpensive manner.

To move Indian chemistry education towards a more advanced global standard through NEP 2020, there have been many recent developments in the policy that have contributed to this effort. A historic accomplishment was achieved with the successful passage of the Anusandhan National Research Foundation (NRF) Bill by Parliament in 2023, which aims to increase centralization and improve research funding to support the advancement of R&D at universities, thus improving the quality of chemical research and creating an environment that encourages innovative high-level research (Aithal & Aithal, 2020).

3. NEP 2020 FRAMEWORK

The NEP 2020 provides a comprehensive framework to make India's educational system (school and university level) compatible with the needs of twenty-first century society. In essence it transforms the nature of education from "what to think" to "how to think," transforming hundreds of years of learning through rote memorization into a competency-based approach. Given the increase in the rate of change caused by advances in technology and increased global connectivity, it is extremely important that students learn through a multidisciplinary approach with an emphasis on integration of technology, so that they are prepared for today's workplace. By breaking down the fixed boundaries of Arts, Science and Commerce, the NEP prepares students to have more cognitive flexibility and the ability to engage in problem-solving, which are needed in today's business environment. Providing vocational education for students in Grades 6 and up also helps students to be prepared for the workforce, so that they are not just degree-holders, but rather highly skilled workers. Ultimately, the NEP provides a foundation upon which to build an educational system that creates "Global Citizens" who are rooted in their own cultural identity, while meeting international educational standards. Some notable changes and framework of NEP 2020 are as below -



- **New Pedagogical Structure:** Replaces the 10+2 system with a 5+3+3+4 model covering foundational, preparatory, middle, and secondary stages.
- **Foundational Learning:** A 5-year Foundational Stage (Ages 3–8) prioritizes play-based learning and early literacy through Preschool to Grade 2.
- **Skill Integration:** The Middle Stage (Grades 6–8) introduces vocational exposure and coding to bridge the gap between academic theory and practical skills.
- **Flexible Secondary Education:** The 4-year Secondary Stage (Grades 9–12) allows students to choose multidisciplinary subjects without rigid streams like "Science" or "Arts."
- **Linguistic Inclusion:** The policy promotes the mother tongue or regional language as the medium of instruction until at least Grade 5 to enhance comprehension.
- **Holistic Assessment:** Evaluation shifts from rote memorization to a 360-degree holistic progress card that tracks cognitive, affective, and psychomotor domains.
- **Higher Education Flexibility:** Undergraduate degrees now offer multiple entry and exit points supported by an Academic Bank of Credits for seamless learning transitions.
- **Multidisciplinary Learning:** Breaks traditional barriers between Arts and Sciences to allow students to explore diverse subject combinations.
- **Tech Integration:** Mandates the use of digital platforms and resources to modernize teaching, learning, and school management.
- **Vocational Skills:** Integrates practical, job-oriented vocational training into the curriculum starting from Grade 6.
- **Teacher Empowerment:** Introduces standardized professional development through frameworks like NPST and the 4-year integrated ITEP.
- **Multilingualism:** Promotes the mother tongue or regional language as the medium of instruction to improve early conceptual clarity.
- **Competency-Based Assessment:** Realigns board exams and school evaluations to test core concepts and application rather than memorization.

4. TRANSITION IN CHEMICAL EDUCATION:

Through an educational revolution, the chemical education system in India is changing from a very theoretical institution-based method towards an all-rounded and integrated course under the National Education Policy (NEP) 2020. The number of graduates from the chemistry field has been produced in India - with PhDs awarded in Chemical Science accounting for just under 20% of total science PhDs awarded in India. However, the system's current duality is evident; with continued promotion of research in Green Chemistry and Nanotechnology by India's premier institutes (the IITs and IISERs) using contemporary teaching methods (e.g. Flipped Classrooms, Virtual Labs) - and at the same time, through an extensive 'Infrastructure Gap' in the Indian education system preventing many rural/state institution students from accessing practical laboratory experiences and learning the craft of chemistry through rote memorization. Of importance to address these gaps, the Department of Science & Technology (DST) and organizations such as ChemAmaze are attempting to use integration of Digital Simulation and Gaming technologies, etc., as a method of bridging the gap for students in order to support a sustainable 'Green' industry (e.g. Pharmaceutical, etc.), and to continue promotion of high-quality practical training with strict academic standards of chemistry education throughout India's chemical educational system.

5. EFFECT OF NEP 2020 ON CHEMICAL EDUCATION:

The NEP 2020 made a historical landmark in educational policies. This policy was made to adapt our traditional education system with new modern touch. NEP 2020 has made a bridge between our ancient education system and modern digital education system. Practical, lab- based streams like chemistry has got a major update due to this policy. As the chemical science subject itself a vocational, professional industrial, and applied field, the students of chemistry faced a drastic upgrade due to NEP 2020.



✓ **Multidisciplinary Research & Subject Choice**

The new education policy removed the barrier of rigid boundaries between 'science', 'arts' and 'commerce' subjects. As a result, huge number of combinations of subjects are available to students. As for example, A student can now major in Chemistry while taking minor courses in Environmental Law or Economics. Later, he can continue his work on chemical engineering or chemical synthesis.

✓ **Structural Changes in Higher Education**

After NEP 2020 Chemistry students of undergraduate levels have to undergo a 4-year Undergraduate Programme (FYUP). This is a biggest change in higher education. In addition there are multiple level entry and exist. Means, If by any chance, a student leaves after one year, he will get a Certificate in Chemistry; after two years, a Diploma; and after three years, a Bachelor's Degree. The 4th year is dedicated to a Bachelor's with Research. this means students now can enter the field of research and paper writing much earlier, gaining hands-on experience in chemical research and synthesis before they even reach their Master's.

✓ **Shift to Experiential & Digital Learning**

The NEP plans to address the lack of infrastructure in rural areas of India by providing Virtual Laboratories, where students can practice chemistry in a computer-generated environment, allowing them to carry out complex or dangerous reactions virtually before attempting them in a laboratory.

Chemistry classes are now moving away from rote memorization of the Periodic Table or mechanistic details towards an understanding of the basis for the properties and behaviours of substances. Assessment and evaluation have also shifted from a focus on 'classroom type' testing to a focus on problem-solving as it applies in the real world within the context of contemporary issues such as Climate Change and Drug Delivery.

✓ **Integration of Indian Knowledge Systems (IKS)**

A new emphasis has been placed on the integration of Ancient Indian Chemical Practices into chemistry education, through the study of traditional metallurgy or dyes or the study of medicinal (Rasashastra) and other chemical practices in conjunction with modern organic and inorganic chemistry. This is being done to provide students with a sense of 'being grounded' in the subject.

Feature	Old System (1986)	NEP 2020 System
Stream	Rigid "Science" stream only.	Flexible; can mix Chemistry with Arts/Music.
Lab Work	Primarily physical, manual experiments.	Blend of Physical and Virtual Labs.
Research	Usually starts at Post-Graduation.	Starts in the 4th year of Undergraduate.
Exit Options	"All or nothing" (3 years or drop out).	Certificates/Diplomas for every year completed.
Technology	Chalkboards, physical models, and printed textbooks.	Molecular modeling software, VR/AR simulations, and AI-driven data analysis.

Table 1: Comparison between old system and new education policy 2020



6. CHALLENGES FOR CHEMICAL EDUCATION:

In a developing country like India, any new policy takes time to be implemented and takes a long time to be successful. so, NEP 2020 will take time. Currently, India is going through the transitional yet challenging phases. Here are some primary challenges facing chemical education in India specially in rural sector.

➤ **Lack of Resources**

There are many significant barriers that inhibit rural chemical education in India. These barriers include inadequate infrastructure, a large shortage of teachers, and a general lack of essential lab equipment. Transportation costs and lack of funds also act as barriers for students' access. Consequently, the government needs to invest in infrastructure and develop modern laboratories and offer comprehensive training programs for educators.

➤ **Lack of Awareness of the Importance of Education:**

Low literacy levels and lack of scientific thinking in rural India are attributable to a lack of understanding of how education creates development. Cultural norms, gender discrimination, and the prioritization of farming work over education can prevent progress. To foster national growth, scientists and technicians must work together with communities to incorporate science and technology into all aspects of life; it is through education that people will end up out of poverty and hunger.

➤ **Less Availability of School and Science College:**

There are very few science colleges and science schools in rural areas; poor transportation infrastructure also decreases the number of girls that complete educational programs. The distance a girl has to travel to school is extremely long, which causes many to drop out. To address this issue, establishing more institutions for education in or near rural areas, along with improving the transportation infrastructure, would significantly reduce the number of students that drop out of school. These two improvements would allow for increased levels of literacy within rural communities.

➤ **Lack of Modern Tools of Learning**

The Indian education system is deficient when it comes to digital resources (specifically Internet and ICT Labs) which creates barriers to achieve the objectives set forth by the National Education Policy (NEP) 2020. A lack of interactive technology and locally produced teaching aids (for example, clay version of molecular models) limits the ability for students to relate chemistry as a subject area to their day-to-day experience. If we are to strengthen our ability to teach science, we must bridge the digital and equipment divide that prevents use of effective science pedagogy.

➤ **Financial challenge**

Most rural families in India have a low economic status, which makes it impossible for them to value education over manual work. Given their low income level, the cost of sending children to school and the expense of necessary chemistry equipment—such as spectrophotometers and pH meters—are prohibitive. Consequently, all schools do not have the capability to teach students how to use the equipment needed for successful careers in the sciences.



➤ **Communication gap**

Language differences are a major obstacle when it comes to chemistry education. English is the first language (the language used for instruction) in most colleges even though there are many local dialects. Most of the rural students who comes from a regional language medium school find it extremely difficult to relate to the concepts being taught. Because of this conceptual gap, the means of communication between the student and a teacher are restricted. The gap must be bridged so that students can reach their goals for a career in the sciences.

➤ **Lack of Quality teachers**

There is a serious need for passionate teachers to teach chemistry, and one of the contributing reasons for this is lower standards for teacher certification and less effective training offered by some for-profit schools. Because chemistry needs teachers with the up-to-date knowledge, ongoing training is important for teachers to continue developing their expertise so their students can understand what they are being taught and achieve academic success.

7. CONCLUSION

There have been significant improvements made to education in India's rural areas. However, there is still miles to go. In order to achieve this, the National Education Policy (NEP) 2020 aims to spread education in rural areas with more facilities, teachers, and infrastructures are being provided even in remote areas. It also aims to provide better education among students with modern teaching learning material and modern technology. However, several major issues need to be mentioned, like Lack of Resources, lack of good buildings or labs in most of the schools. There are very few good teachers in Chemistry. Chemistry, as a subject, faces a number of problems, as it requires experiments and real-life examples to be understood clearly. To overcome this, technology can be used to fill this gap, as most of the experiments in Chemistry require practical implementation, which might be difficult to achieve in most of the schools. Nevertheless, the NEP 2020 presents a major opportunity to address the many challenges faced in the schooling of rural students, especially in the subject of science, to provide quality education to every student in the country.

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