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National Education Policy 2020 with Reference to Chemistry Education

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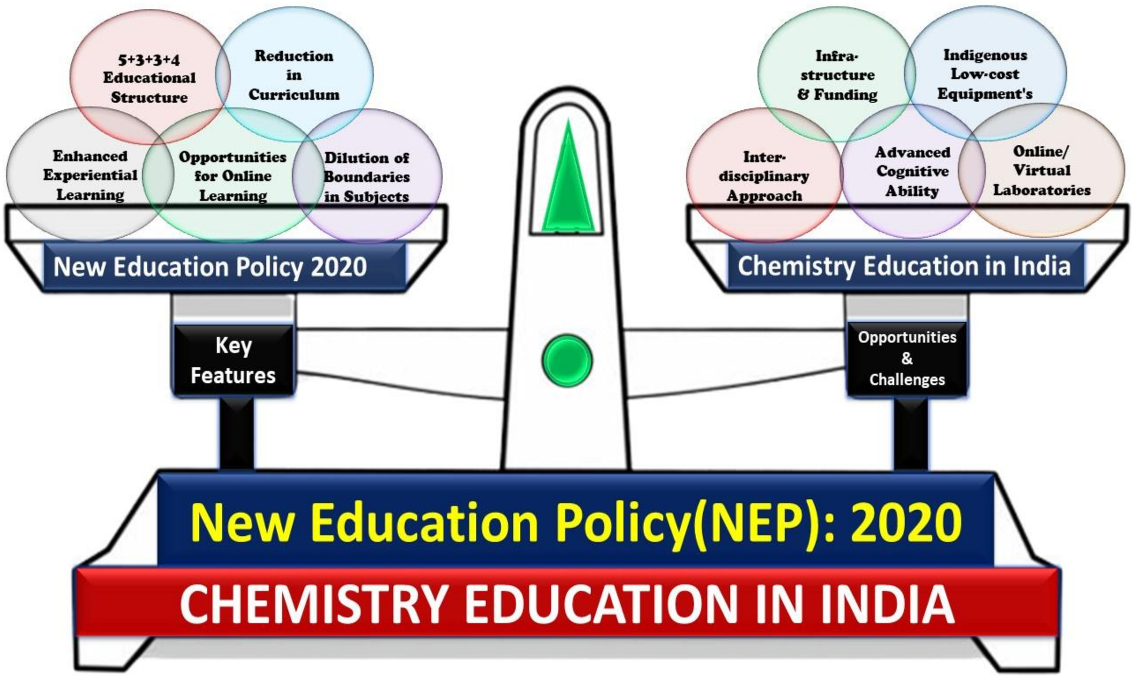
Abstract: *India's "demographic dividend" offers a strong foundation for investigating a multitude of opportunities in the domains of research and education, particularly following the approval of the new National Education Policy (NEP) in 2020. With a focus on experiential learning and higher-order thinking skills, NEP 2020 proposed radical changes to the educational system at both the high school and college levels. Other changes included teacher training, innovative and technique-based pedagogy, online learning, and a completely new academic structure. We have examined a concise overview of the current state of chemistry education and research in India, taking into account these suggested modifications to the educational system. Studies have shown that an increasing number of students are opting to major in science, with chemistry being the most popular choice, accounting for almost 20% of all scientific PhDs granted in India. The significance and caliber of Indian research publications were also discussed. We finally examined the issues that India's chemical education system faces and investigated potential solutions based on the recently approved NEP in order to maximize the country's potential for chemical education and research.*

Keywords: Chemical Education and Research, Public Understanding, Outreach, History, National Education Policy 2020, Demographic Dividend of India

I. INTRODUCTION

National Education Policy 2020: Need of the hour

The education and research fields in India are expected to have a bright future due to the consistently rising output in these areas as well as government initiatives, large funding, and improved infrastructure. This revolution may be sparked by the recently passed National Education Policy (NEP 2020), which aims to significantly alter education in both secondary and postsecondary settings. Education research has always been crucial in determining a nation's educational policies [1–5]. A three-level framework developed by Ion and Iucu—the "Micro" or "Researcher" level, the "Intervention-Organizational" level, and the "Macro Systemic Level of Educational Policies"—shows how closely education, research, and policies are related [4]. The fundamental conclusions of research are vital, and these must subsequently be put into practice and disseminated throughout the organizational levels to produce policies that are grounded in factual or empirical research. The introduction of NEP 2020 could mark a turning point in the history of the Indian education system, given the country's current state of flux. Changes to the fundamentals of education in this country were imperative given the scientific, technological, and innovative advances of the 21st century. The extensive list of recommendations of various official policies are found here [6]. Over two-thirds of India's population falls within the working-age range of 15 to 59 years old, making it a young and vibrant nation. Over half of India's population is under 25 years old, and over 65% is under 35. India's under-25 population is expected to account for roughly 25% of the global population within the next ten years. India boasts the largest population in the world in the 5–24 age group, with over 500 million people, and 26.62% of the country's total population falls into the 0–14 age group [7]. NEP saw the window of opportunity and plans to seize it. The demographic data makes abundantly clear what an amazing opportunity it presents for the fields of scientific research and science education. Young people, who represent the nation's future, can undoubtedly be impacted by improvements made to the educational system. If appropriately trained, this sizable population of approximately 25-year-olds may also inspire and encourage the subsequent generation of students to choose a career in chemical science.



II. SILENT FEATURES OF NATIONAL EDUCATION POLICY -2020

A new education policy was desperately needed to keep up with the rapidly changing educational landscape since the previous NEP was implemented several decades ago. A detailed analysis of NEP reveals both its advantages and disadvantages. Some of NEP's most notable benefits are listed below.

- Since age three is recognized to be a crucial period for brain development, the new educational structure (5 + 3 + 3 + 4) will guarantee that basic education begins at a very young age [8]. These four distinct phases are called Foundational (3 years of preschool + grades 1–2), Preparatory (grades 3–5), Middle School (grades 6–8), and High School (grades 9–12). This new educational structure closely resembles the American educational system's Elementary, Middle, and High School divisions.
- Many elementary school pupils do not possess foundational literacy and numeracy skills, which include the capacity to read and understand simple texts and perform simple calculations. State and union territory governments will need to develop an expedient implementation plan to support NEP 2020's goal of achieving that by 2025. The curriculum will be updated, teachers will receive specialized training, and high-quality resources will be provided to help them accomplish this.
- A major emphasis on experiential learning has been placed by NEP 2020. Enhancing students' critical thinking abilities, fostering their scientific curiosity, and expediting meaningful learning in a clever, efficient manner are the goals [9-10].
- The hallmarks of the new curriculum system will be holistic development, a broad choice of subjects, and dilution of rigid boundaries among various disciplines. The program will include vocational training as well. As a result, students will have greater freedom to concentrate solely on the subjects that they find engaging and interesting.
- A key component of NEP 2020 has been its Interdisciplinary approach and research. Multidisciplinary Education and Research Universities (MERUs) are going to be constructed as part of a push toward multidisciplinary research and education.

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- Only the most important and necessary subjects will remain in the curriculum. This will guarantee that pupils don't take on too much work.
- Coding and computational skills are taught to students in middle school.
- Students' understanding and not their memorization abilities will be evaluated by moving toward formative and competency-based assessment, peer assessment, and testing higher-order skills.
- Online learning received a lot of attention, which is important, particularly in pandemic period. It is admirable that NEP recognized the potential benefits of remote learning in India well in advance of the COVID-19 pandemic.

III. ISSUES OF CONCERN OF NATIONAL EDUCATION POLICY 2020

There are still some important areas of concern that need to be addressed, even though NEP 2020 has addressed some important issues pertaining to the educational system and can be vital in reforming the system.

A number of proposals mentioned in the NEP lack specificity or guidelines. It could be extremely challenging to implement a lot of recommendations without a precise and well-defined roadmap [11].

A steady stream of funds is needed to complete this enormous undertaking, so funding is another major worry. The proper implementation of NEP alone will cost over $30 billion [12].

A big challenge remains in implementing some of the proposals discussed in NEP. For example, increasing the Gross Enrollment Ratio in higher education or bringing back 20 million students to school requires a lot more groundwork. To attend this goal in 15 years, one new university and 50 new schools are needed to be opened every week in India, which is a herculean task [13].

The paucity of instructors with the necessary training is another major source of worry. The use of experiential learning methodology with such a vast student body across India will require the hiring and proper training of more teachers.

The Indian education system stands to gain a great deal, which will ultimately aid in the country's education and research in science and chemistry, if the concerns are duly addressed and a comprehensive implementation roadmap for the NEP proposals is supplied.

IV. CHALLENGES IN IMPLEMENTATION OF NATIONAL EDUCATION POLICY 2020

Despite the potential for significant impact on India's educational system, the recently proposed National Education Policy (NEP) faces practical implementation challenges in such a vast and heterogeneous nation. It would take a coordinated effort at the National, state, institutional, and individual levels, as stated in NEP 2020, that "Any policy is only as good as its implementation." The last few years have been effectively used to raise awareness of the NEP, despite being marred by the COVID-19 pandemic. Like the two prior policies, NEP 2020 also addressed issues of equality and access in addition to educational quality. As such, the task at hand is far more daunting. Individual states will need to take on more duties and adhere to the framework set forth by the central government in order to implement it successfully. Since they serve a sizable portion of the student body, the private sectors must also contribute. Depending on the specifics of a given recommendation, challenges and barriers may differ, but two are generally consistent across disciplines: qualified teachers and adequate infrastructure. For both of these to be implemented, a sizeable sum of money and a specific amount of buffer time are needed. Acknowledging this, none of the suggestions are intended to take effect right away. Based on the magnitude of the challenges at hand, a few landmark years (2025, 2030, 2035, and 2040) have been designated as the deadlines to achieve specific goals. It is unlikely that all the states will have their implementation plans ready at the same time, even though some parts of the NEP are meant to be implemented right away. Instead, it would be implemented gradually based on how prepared certain states are, with others following suit. Regular reviews of the completed actions will help steer future implementations and correct course as necessary.

Funds for the NEP have already been set aside by the federal and state governments, and the education sector has received the largest-ever pledge of 6% of India's GDP. It might not be realistic to expect all schools and colleges to have adequate lab facilities at first. However, there will be groups of well-kept labs at specific universities or colleges where students from the neighborhood can come use the resources. Lastly, internal training programs are already in place to address the issue of teachers' lack of empowerment, even though it may persist at first. The National Initiative for School Heads and Teachers Holistic Advancement, or Nishtha, is a program that the central government started to improve the quality of education in schools by implementing integrated teacher training [14]. In addition, a number of universities including prestigious ones like IISc, IITs, IISERs, and others offer teacher education programs in an effort to close this gap. Through lectures and practical training, the Talent Development Center (TDC) at Challakere IISc Campus provides science and mathematics education to High School and Pre-University Course (PUC) teachers [15-17]. Due to government's generous support, more than 6500 teachers have already taken part in these programs.

V. CHALLENGES AND OPPORTUNITIES FOR CHEMISTRY EDUCATION IN NEP 2020

"Whenever there is a challenge, there is also an opportunity to face it, to demonstrate and develop our will and determination." - Dalai Lama

5.1 Experiential Learning:

The NEP 2020's emphasis on "play/activity-based learning during the "foundational" and "preparation" stages and "experiential learning" during the "middle" stages is commendable [6]. This method may help students participate in interactive learning activities, improve their learning abilities, and gain a foundational understanding of chemistry [9-10]. Through practical exercises and experiential learning, students should be able to conduct basic experiments ranging from basic chemistry concepts (matter, changes, etc.) to slightly more complex concepts (acids-bases, chemical reactions). Students can use model kits or online simulations to learn by reflecting on their activities when studying subjects like chemical bonding, atomic structure, etc., for which conducting hands-on experiments may be challenging. The famous quote from American educational reformer and philosopher John Dewey goes, "Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results." However, putting experiential learning into practice in all Indian institutions is actually quite challenging. While some urban schools and other institutions might be more prepared for it than others. Accordingly, to give students the best possible setting for experiential learning, a substantial investment and a thorough overhaul of the infrastructure are required. Furthermore, the majority of teachers also lack experience with experiential learning approaches, so they also require appropriate training. In order to foster students' critical thinking abilities, encourage them to ask questions, and ultimately result in more meaningful, cohesive, and integrated learning, assessments should be created with this in mind.

5.2 Financial Support

The majority of funding for higher education comes from the state and central governments, through the Department of Higher Education in the Ministry of Human Resource Development (MHRD), which has an annual budget of Rs 47,65,768 crore for 2024–2025. A tiny portion of public funds are invested by the private sector in higher chemical education, mostly through their institutions. Funding for research is still largely provided (about 65%) by the central government. The Department of Science and Technology (DST), the Department of Biotechnology (DBT), the Department of Atomic Energy (DAE), the Council of Scientific and Industrial Research (CSIR), the Indian Space Research Organization (ISRO), the Ministry of Earth Sciences, and the Science and Engineering Research Board (SERB), a recently established autonomous body by an act of parliament, are the main funding agencies. The budget allocated to these central scientific ministries and departments rose from Rs. 4.4 billion in the fifth Five-Year Plan period (1974–1979) to Rs. 236 billion in the tenth Five-Year Plan period (2002–2007), to Rs. 475 billion in the eleventh Five-Year Plan period (2007–2012), and finally to Rs. 1.2 trillion in the twelfth Five-Year Plan period (2012–2017). Many modern fields of study, including chemistry, are supported by these departments, which are driven by curiosity and individuality. Numerous collaborative funding schemes are available in these departments, specifically for chemistry research, with scientists from various countries such as the USA, Canada, UK, France, Germany, Australia, and Singapore, among others. Although most funding is allocated to start and continue scientific and chemical research projects, the amount and distribution of educational funding in the last ten years across the nation also show how things are changing and how many people are participating, as opposed to a small number in the early 1970s and late 1980s. Institutions that are funded centrally, such as universities, are provided with infrastructure and operational grants by the University Grants Commission (UGC) and the Ministry of Human Resource Development (MHRD). These grants cover salaries and benefits for faculty and staff during retirement. Furthermore, a significant increase in university share for research has been achieved as a consequence of DST funding infrastructure development in numerous higher education institutions. As a consequence of this support, Indian chemists have contributed more to research publications as has been mentioned previously. The Indian Institute for Science Education and Research (IISER), a group of seven new educational and research institutions founded by the Ministry of Human Resources and Development (MHRD) a few years ago, is a major boost to supporters of Indian science because it integrates higher education and research across the board. Seven IISERs have been established so far across the country, namely IISER Pune in Maharashtra, IISER Bhopal in Madhya Pradesh, IISER Mohali in Punjab, IISER Kolkata in West Bengal, IISER Thiruvananthapuram in Kerala, IISER Tirupati in Andhra Pradesh, and IISER Berhampur in Odisha. Though most of the students who enrol in IITs and IISc have a technology orientation, these institutions have been instrumental in producing the majority of high calibre research in chemistry and chemical engineering since their founding. Despite the fact that the majority of IITs are home to many Ph.D. holders in science, the establishment of seven IISERs and capacity building initiatives in India over the past ten years have made it nearly impossible for scientists to conduct low-quality basic science research; even with their substantial funding, there is little doubt that these institutions will produce high-quality work. IISERs should lead science in the upcoming era, particularly chemistry and chemical research, if they are provided with the same level of intellectual and financial support as the IITs, which to date have produced global leaders in technology. Furthermore, the Department of Atomic Energy and the University of Mumbai have initiated the Centre for Excellence in Basic Sciences in Mumbai and initiated a four-year integrated science undergraduate program at IISc. Such actions require decades-long government commitment. The establishment of several such institutes with top-notch faculty and research facilities is also mentioned, indicating that science will become a viable and interesting career choice for intelligent young people. This will help basic research at the physics, chemistry, and biology interfaces.While India has seen a significant increase in the number of schools, colleges, and universities, the demand for seats is rising in tandem with the country's population growth. Regretfully, there is a significant mismatch between supply and demand, and recommendations for the construction of an extra 200,000 schools, 35,000 colleges, and 700 universities were made in a recent report from the India Brand Equity Foundation (IBEF) [7]. To make matters worse, aside from a select few high-end facilities, most still lack the fundamental frameworks needed for chemistry labs. A significant amount of funding is required to meet this enormous demand. The Indian government has already committed $400 million to Revitalizing Infrastructure and Systems in Education (RISE) by 2022, as stated in the union budget 2020–21, but that amount might not be sufficient. The private sector must step up and make significant investments in chemistry education as well. Businesses in the education sector are anticipated to receive over $500 million in funding from venture capital and private equity firms. The field of online education has seen a large influx of start-ups that are drawing significant investment. The proposal to establish foreign universities in India in NEP 2020 has the potential to revolutionize higher education. In addition to guaranteeing cutting-edge facilities, it will also entice international investors to make significant investments in India's developing chemical education sector.

5.3 Current initiatives to reintroduce science and chemistry to the classroom:

Postgraduate fellowships were exclusively offered to scientists until 1999. At that year, the Kishore Vygnanik Protsahan Yojana [17] (also known as the Budding Scientists Encouragement Scheme) was launched as a science induction program. Full undergraduate and science education at accredited universities was offered through the scholarships. INSPIRE [18], an acronym for Innovation in Science Pursuit for Inspired REsearch, is a different program that was initiated in 2008. The latter has awarded roughly 47,000 scholarships to deserving youth enrolled in science programs thus far. The current gap between undergraduate (UG) education and research is being addressed by a number of other programs, including the Summer Research Fellowship Program (SRFP) offered by the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bangalore, the National Initiative on Undergraduate Science, and the Visiting Students Research Program by TIFR, Mumbai. Even though UG students are the target audience for these programs, small college teachers can also benefit from the opportunity to gain research experience. Biannually, the CSIR administers a national examination for admission to science doctoral programs. A total of 2,19,146 students registered for the December 2023 exam, of which 5326 passed (1535 in chemistry). Around more than 1000 doctoral fellowships to university toppers are awarded by the INSPIRE program annually. To date, about 5000 research fellowships have been awarded out of which thirty percent have been awarded in the chemical sciences only. This does not, however, include fellowships released from projects funded to faculty across the nation as well as fellowships given by the Ministries such as the MHRD (which funds IISc, IITs, and NITs and their postgraduate student scholarships directly); these are analogues of research and teaching fellowships provided by US universities from university teaching and research funds, and at any given time, all of these lead to government support for approximately 70,000 full-time Ph.D. students. A number of new science programs were also launched during this time to modernize the infrastructure of universities and academic institutions. Two of these programs are FIST (Fund for Improvement of Science and Technology infrastructure) and PURSE (Promotion of University Research and Scientific Excellence) [19]. Research in the university sector has been rejuvenated as a result of funding from these and other programs; this is demonstrated by the rise in the share of scientific publications from universities from 15% of all research from India in 2003 to 31% in 2010. FIST was established in 2000 and has funded over 2100 departments and colleges with a financial outlay of Rs. Nineteen billion (the chemistry share is Rs. 4.6 billion, or 23.8% for 662 departments). Since PURSE's launch in 2009, 44 universities have benefited from its Rs. 3.3 billion total budgets.

5.4 Building Capabilities for Higher-Order Thought

The majority of classroom instruction and examinations focus more on memorization than on critical thinking and original thought. This is where it becomes critically important to support meaningful learning and theoretical and experimental problem-solving. For the first time, NEP supports various methods of assessment in order to encourage students' higher-order thinking skills (HOTS) [20-21]. In 2016, the Central Board of Secondary Education (CBSE) mandated that 10−20% of the questions in the HOTS for secondary and senior secondary exams be answered correctly. According to Madhuri et al., inquiry-based learning significantly increased HOTS during chemistry lab sessions compared to traditional lab sessions. Additionally, participants were able to recognize the significance of the pertinent ideas in light of actual issues. According to Ramani et al., using active learning pedagogy helped students in schools develop HOTS. These studies demonstrated that the development of HOTS requires both student participation and experiential, inquiry-based learning. However, it was discovered that institutional and structural elements were also essential for the development of HOTS. Bhattacharya et al. demonstrated that the two primary causes of students' incapacity to understand HOTS concepts were institutional barriers and evaluation procedures by analysing the effects of three key variables (students, teachers, and institutions) on HOTS learning. Gupta et al. noted that teaching HOTS is just as challenging as learning HOTS, and they proposed that the way to address this is through a comprehensive reform of the Indian school curriculum and teacher training [22]. All of these studies suggest that in order to foster critical thinking abilities in Indian students in the field of chemistry education and science education in general, educators, institutions, and regulatory bodies must work together.

5.5 Low-Cost Locally Manufactured Equipment and Microscale Chemistry

A special emphasis needs to be placed on locally made, inexpensive, low-maintenance equipment because financial constraints are a big issue in developing nations like India. The Committee on Teaching of Chemistry (CTC) endorsed the idea of enabling chemistry experiments even in elementary school, giving students the chance to engage with experimental chemistry from a young age. The construction of the equipment has gained popularity, and UNESCO and IUPAC-CTC have published instruction manuals for the same. Another way to solve this problem is to use microscale chemistry kits, which are less expensive than real lab equipment and glassware but still allow students to perform simple chemistry experiments, piquing their interest in science and increasing their curiosity. These microscale chemistry kits are already produced and sold by a number of businesses, and in the years to come, demand for them will only increase [23]. This could be a useful tool for introducing students to experiential learning in the classroom. By supplying science kits to children in rural India, a number of nonprofit organizations including the India Literacy Project (ILP), Agastya International Foundation, and Janyaa Foundation, to mention a few are setting an excellent example for experiential learning.

5.6 Inter/Multi-disciplinary Methods

The implementation of an interdisciplinary approach to teaching facilitates students' acquisition of a deep and comprehensive understanding of complex issues, ultimately leading to a more complete, coherent, and holistic understanding. However, one of the main challenges facing India's chemistry education system is overcoming the subject's isolated and localized nature. Whenever possible, chemistry should be taught in relation to both physics and biology, as many biological processes are interconnected with chemistry, and physics sometimes plays an important role as well. Therefore, it makes sense to establish connections between these subjects so that students can relate to these concepts in their everyday lives. Attracting the interest of certain students who might otherwise gravitate toward biology or physics instead of chemistry would be beneficial. One could draw connections between physics, chemistry, and biology when teaching "photosynthesis" or "human vision," for instance, or between physics and chemistry when teaching "battery operation." As such, a key component of implementing NEP could be an integrated, multidisciplinary approach to instruction and evaluation.

VI. ONLINE LEARNING

6.1 Efforts to Provide Wide-Reaching Chemical Education and Certification Through Online Means:

When it came to technical courses, the National Program on Technology Enhanced Learning (NPTEL) [24] officially introduced massive online open education in India during the Internet era in 2003. With expert assistance and guidance from Carnegie Mellon University in Pittsburgh, this program was drafted by the IITs. At the same time, The MIT, Cambridge, announced Open Courseware, which was a rather fortunate coincidence [25]. Both the National Mission on Education through Information and Communication Technology (NMEICT) [26] and the NPTEL were fully funded by the Indian government, which also introduced them in 2009. Many curriculum-based courses in chemical engineering and chemistry have been made available since 2012 under these two initiatives. Under NMEICT, NPTEL was awarded Rs. 204.7 million for the first four years (US $5.5 million in 2003) and Rs. 960 million (US $21 million) for the year 2009. About 80 courses in chemical engineering and more than 50 postgraduate courses in chemistry alone are almost finished. Many other disciplines are covered by the project. Courses can be used for self-study or as a supplement to university curricula, with content equivalent to 40 lectures of each one hour. The National Knowledge Network (NKN) and NMEICT launches, which enabled gigabit connectivity between national research laboratories, universities, and elite academic institutions, have aided in the development and distribution of content for students studying management, arts, science, commerce, humanities, and other related disciplines through the use of ICT tools. The materials can be edited and used for other purposes. They are freely accessible. Thanks to IIT Delhi's collaborative efforts with ten or more other partner institutions, virtual laboratories in the fields of engineering and chemical sciences have already started to take shape [27]. The Creative Commons License Share-Alike and Attribution, which Wikipedia also uses, is currently in effect for distribution of these files. There are plenty of opportunities to increase student engagement and excitement in science, especially chemistry, with the advent of development tools and massive open online courses (MOOCs) [28] offered by prestigious academic institutions with government funding. National agencies are now implementing extensive teacher training programs that will help mold the next generation of educators by introducing pedagogical tools for learning and outcome-based learning. After the central government realized the benefits of online learning a few years ago, a significant portion of NEP 2020 was allocated to this area of instruction. However, there are many challenges associated with online learning in India, particularly with chemistry [29]. A relatively small percentage of students have access to computers and the Internet [30] Since computers and fast Internet connections are essential for online learning, it is important to make sure students have the tools they need and that they can afford the necessary expenses. Furthermore, teachers require adequate training because not all of them are conversant with online instruction and related resources. Real-world experiments play a major role in chemistry education, which makes online learning challenging. The Journal of Visualized Experiments (JoVE) is a source of peer-reviewed papers supplemented with experimental methods and protocols in video format. Other online resources for teachers include the many websites that offer "virtual laboratories" (PhET, Labster, Chemcollective, Beyond Labz, PraxiLabs, etc.) covering important chemistry topics; these cannot replace benchtop chemistry, but they can definitely provide basic ideas about how to carry out chemistry experiments safely and fruitfully. In India, a number of institutes are involved in creating virtual lab simulations across disciplines (chemistry, physics, biology, and engineering); this is a government-funded project. Additional apps and websites aimed at educators. Two examples of government-funded platforms are Diksha and Swayam; the other platforms are privately owned. IIT Bombay, one of India's best universities, offers an interdisciplinary program in educational technology that focuses on teaching and research in the areas of pedagogy and state-of-the-art tools for technologically enhanced learning. Whether chosen singly or in concert, each of these decisions is essential to improving online learning. The majority of students expressed satisfaction with online learning and acknowledged its importance despite its obvious disadvantages [31].

VII. CHALLENGES AND OPPORTUNITIES

The government has initiated several programs to guarantee that India has access to high-quality chemical education; however, the authors identify four key stakeholder groups that will need to drive and benefit from this. According to demographic studies 18, India is predicted to account for nearly 25% of the world's under-25 population within the next ten to fifteen years. Any attempt to raise the standard of education in India will be a deadly threat to the growth of the biggest democracy on earth, so this needs to happen right now. Due to the fact that there are currently 18 million full-time college students (of which roughly two million study chemistry alone) and that number is worryingly rising, all stakeholder groups have a great deal of responsibility and opportunity. Also, the gross enrollment ratio (GER) for the higher education sector remains at 20%. A list of the parties involved is provided below:

- Members of professional associations such as the Chemical Research Society of India, along with academicians and scientists employed in Indian universities and research facilities.
- The government and reputable scientific organizations responsible for developing, providing funding for, and implementing policies; the chemical industry in India and globally.
- Academic organizations, international universities, and professional science associations worldwide are managed by the ACS and RSC.

In order to significantly raise the standard of chemical education and research output, cooperation between one or more of the previously mentioned groups may be necessary. The remaining part of this section addresses these opportunities in relation to the learning stages and potential roles of stakeholders. The opportunities that have been created for the groups have greatly outweighed the challenges that they faced.

7.1 School Education (Secondary and Higher Secondary Levels)

The programs that Indian students choose for their higher education are largely influenced by their parents, who almost always also provide the funding for it. High-quality chemistry education and research programs are necessary in India to win over parents. Introducing paradigms and objective/purposeful learning into the classroom is essential to changing the perception of science from one of rote learning to one of excitement and a subject that can change societies. This can be accomplished by teaching students about historical inventions and discoveries and having them participate in quick but insightful hands-on demonstrations. The development of easy-to-use and efficient game-based learning techniques is one of the most fascinating educational opportunities made possible by ICT and the Internet. The science curricula in schools will require a significant revision in the upcoming years. Students should not be assessed based on rote memorization or replication, and teachers must strictly follow pedagogical approaches in the classroom.

7.2 Higher Education (Graduate and Post-Graduate Levels)

More real-world examples and concepts that have an immediate bearing on employment, research, or inventions ought to be taught and forgotten at the college level. Programs need to be carefully designed in order to accommodate a range of learning goals. For focusing needs, NPTEL, NMEICT, and the global Open Educational Resources are great resources. Credit transfer programs must include innovative learning opportunities like MOOCs, flipped classrooms, and the like if an institution does not possess the necessary core competence. Additionally, it's critical to consider actively involving college students in creative projects where their faculty can contribute significantly. Given the widespread accessibility and dispersion of the Internet and cloud, research teams from esteemed universities might find that open-ended problems present viable initiatives. The current program years differ significantly (three years UG, two years PG, four years UG, and five years combined UG-PG with exit in between or not); therefore, to maximize this diversity, major subjects and electives must be offered through a flexible credit system. For each of these programs, the current offerings in terms of electives and courses are somewhat restricted. Extensive student exchange programs have already been established between Indian engineering colleges and western nations. Using MOOCs to expand science initiatives to chemistry and other fields in India, a country with a high concentration of science and arts colleges, is another way to address the disinterest of students in science degrees and the relatively low number of motivated undergraduates in science programs. The second-largest student population for MOOCs offered by most American universities is already well known to exist: Indian students. Formalizing the same through interactions with the Indian government and academic/university regulatory bodies is advantageous to everyone. The systematic deterioration of chemistry education brought about by many universities' inadequate lab facilities and instructional infrastructure requires immediate investigation. Most universities are owned by state governments, which also make very little to no investment in educational infrastructure. In addition to the central government's efforts to improve chemical lab infrastructure through FIST, physical and virtual laboratories must be built to improve the quality of learning concepts through experiments. A greater number of laboratories ought to be constructed. To effectively instruct the YouTube, Twitter, Facebook, and mobile generation in experimental chemistry, highly educated faculty members in India and abroad need to seize this opportunity to innovate and enhance their technical and ICT skills. Numerous American universities, along with initiatives from ACS, NSF, and The Royal Society, are tackling this issue well ahead of schedule. Author MSK vividly recalls his initial excitement upon discovering the IrYdium Project, a virtual chemistry lab developed in 1999 by David Yaron of Carnegie Mellon University [32]. The creation of OCW courses by MIT Cambridge, the Open Learning Initiative of CMU, [33] MOOCs, and NPTEL show that chemical education in India can be advanced to a new level with the help of both internal models and external support.

7.3 Use of Online Learning Pedagogies:

While many of the latest innovations in the Internet focus on delivery strategies and giving users access to a vast chemical knowledge base, they don't always effectively support learning: As David Merrill puts it, "Information is NOT instruction [34]. Learning pathways determined by results and relevant taxonomies. There must be twenty-three learning areas covered in the current curriculum, which must be exacting and outcome-based. A number of IITs in India are currently testing MOOC certification and developing online curricula. This suggests that a significant amount of chemical education materials still need to be developed in order to help different learners achieve their specific career goals. It is essential that career incentives—which don't always have to be financial—provide educators with continued training. India's teacher-to-student ratio is significantly lower than what is deemed appropriate globally. Right now, there's a big hole that needs to be filled by the online courses. Academic incentives, proctoring, and certification for teacher preparation are provided to MOOC course participants. MOOCs can be made to highlight difficult chemical ideas and offer imaginative justifications using a ton of innovative examples from the most recent research. Industries can provide MOOCs to help students grasp chemical processes by providing them with a strong foundation. Additionally, they could include instruction on how to use virtual labs and animations to improve conceptual learning through technology. MOOCs are already being tested in a number of countries, including India, where their use may help close the shortage of highly skilled educators. MOOC proponents are currently trying to create courses for everyone, but the paradigm shift in teaching-learning that MOOCs envision is better suited to career orientations and teacher training.

7.4 The role of government agencies and institutions that receive government funding:

Law, medicine, and agriculture are just a few of the academic disciplines that require strong ties to chemistry. Pre- and para-clinical subjects, novel chemical and biochemical processes, ethics, environmental science, and forensics are some of these fields. But these fields ought to work together more as they currently operate separately. The government should push universities to offer a wide range of disciplines; interdisciplinary programs will be far more fruitful and successful when the foundational courses in each discipline are reinforced, provided on the same campus, and have enough credit transfers between them. Adequate knowledge of foundational subjects is necessary for the successful implementation of interdisciplinary programs. They often have great success at the master's level. Undergraduate disciplines that are blindly introduced to specialty courses such as information technology, biotechnology, and nanotechnology need to be carefully reviewed and, if possible, dropped. Respected chemical research institutions, like

IITs, IISc, and others, must develop successful outreach programs for students living in rural regions. They must promote required visits by teachers and students from secondary and postsecondary institutions and increase interactions because the current state of chemistry is sorely lacking in vitality and awareness. Notably, IISc established a Talent Development Center24 to help train high school educators in Karnataka. These kinds of initiatives would be essential across India.

7.5 Role of Industrial and International Partners:

The chemical industry and chemistry researchers worldwide need to be directly involved for innovations in curriculum design to begin at colleges. Many international chemical companies have made a name for themselves in India as research-focused players. This presents a great opportunity to develop new curricula that facilitate the establishment of academic campus laboratories for industrial research and development. Chemical companies can either recoup the costs out of a sense of corporate social responsibility, or they can use their research facilities to support academic research by charging for access to specific areas. The majority of academic institutions nowadays struggle with subpar lab space and a lack of dedicated time for students to gain practical laboratory experience. This could be enhanced if faculty members were trained in industrial research laboratories. The chemical industries may be encouraged to establish research laboratories on university property and to undertake longer-term research and development projects in collaboration with academic staff and students. These kinds of practices are standard in the US and other Western countries. State governments may find it difficult to commit long-term funds for these programs. Therefore, in addition to providing access to facilities, significant funding from the private sector would be required. These kinds of laboratories also function as work environments that promote innovation and creativity. Young and aspirational undergraduate students and research scholars may be supported by funds under corporate social responsibility, which are also encouraged by tax schemes.

VIII. CONCLUSION

There are many opportunities as well as challenges in the path of advancing chemistry research and education throughout India. In this paper, we have reviewed the current state of science education and research in India with respect to chemistry and general science. India had great potential, as we have shown, but its research output at the beginning of the twenty-first century was less than that of several other countries. Since then, though, things have gotten better as more and more Indian researchers are opting to work in the field of chemistry. After China and the United States, India currently produces the third-most chemistry papers globally. The quantity of Indian publications with a chemical focus has likewise grown consistently over time. To make this possible, the Indian government has launched a number of initiatives with strong backing from the business community. At this crucial point, NEP might be the ideal spark to propel this movement forward. As was previously mentioned, a few challenges and issues need to be overcome in order to implement the NEP's recommendations. If these challenges are overcome, India will actually make progress in the areas of chemical education and research, enabling it to ultimately fulfill the enormous potential that it has consistently demonstrated. The National Education Policy 2020 is thus the first constructive step. The success of NEP 2020 will determine the direction of science education in this country, particularly chemistry education.

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REFERENCES

[1]. Whitty, G. Education(al) research and education policy making: is conflict inevitable? British Educational Research Journal 2006, 32 (2), 159−176.

[2]. Burns, T.; Schuller, T. The Evidence Agenda. Evidence in Education: Linking Research and Policy 2007, 15−30.

[3]. Bandur, A.; Hamsal, M.; Furinto, A. 21st Century Experiences in the Development of School-Based Management Policy and Practices in Indonesia. Educational Research for Policy and Practice 2022, 21 (1), 85−107.

[4]. Parker, R.; Thomsen, B. S.; Berry, A. Learning Through Play at School − A Framework for Policy and Practice. Front. Educ. 2022, DOI: 10.3389/feduc.2022.751801.

[5]. Ion, G.; Iucu, R. Does Research Influence Educational Policy? The Perspective of Researchers and Policy-Makers in Romania. European Higher Education Area 2015, 865−880.

[6]. National Educational Policy (NEP), 2020. https://www. education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_ 0.pdf

[7]. India Brand Equity Foundation (IBEF) Report 2020. https:// www.ibef.org/archives/industry/education-reports.

[8]. Tierney, A. L.; Nelson, C. A. Brain Development and the Role of Experience in the Early Years. Zero to Three 2009, 30 (2), 9−13.

[9]. Goldman, J.; Kuper, A.; Wong, B. M. How Theory Can Inform Our Understanding of Experiential Learning in Quality Improvement Education. Acad. Med. 2018, 93 (12), 1784−1790.

[10]. Agustian, H. Y.; Seery, M. K. Reasserting the role of prelaboratory activities in chemistry education: a proposed framework for their design. Chem. Educ. Res. Pract. 2017, 18 (4), 518−532.

[11]. Khatak, S.; Wadhwa, N.; Kumar, R. NEP,2020-A Review cum Survey Based Analysis of Myths and Reality of Education in India. Int. J. Adv. Manage., Technol. Eng. Sci. 2022, 12 (1), 12−22.

[12]. Venkateshwarlu, B. A Critical Study of NEP 2020: Issues, Approaches, Challenges, Opportunities and Criticism. Int. J. Multidiscip. Educ. Res. 2021, 10 (2), 191−196.

[13]. Nishtha (National Initiative for School Heads' and Teachers' Holistic Advancement). NISHTHA. National Portal of India. https:// www.india.gov.in/spotlight/nishtha.

[14]. Teachers Training Programme. https://odaa.iisc.ac.in/ teachers-training-programme.

[15]. Teaching Learning Centre. https://www.iitm.ac.in/academics/ learning-for-all/teaching-learning-centre.

[16]. Centre of Excellence in Science and Mathematics Education (CoESME). https://www.iiserpune.ac.in/engage/outreach-andtraining/coesme/programmes.

[17]. Kishore Vygnanik Protsahan Yojana (KVPY). http://www.kvpy. org.in

[18]. DST INSPIRE Programme: Report and Recommendation from Academies' Advisory Panel 2010. http://www.inspire-dst.gov.in/ INSPIRE_Academy_Panel_Report_2010.pdf.

[19]. Report of Bibliometric Study Commissioned to NISTADS by DST (reference to FIST and PURSE); Science, Technology and Innovation Policy, Ministry of Science and Technology, Government of India: 2013; http://www.dst.gov.in/sites/default/files/ Salient%20Highlights%2C%20Elsevier%2C%20Scopus%20Report%20%2831.5.16%29.pdf

[20]. Fensham, P. J.; Bellocchi, A. Higher order thinking in chemistry curriculum and its assessment. Thinking Skills and Creativity 2013, 10, 250−264.

[21]. Madhuri, G. V.; Kantamreddi, V. S. S. N.; Prakash Goteti, L. N. S. Promoting higher order thinking skills using inquiry-based learning. Eur. J. Eng. Educ. 2012, 37 (2), 117−123.

[22]. Gupta, T.; Mishra, L. Higher Order Thinking Skills in Shaping the Future of Students. Psychol. Educ. 2021, 58 (2), 9305−9311.

[23]. Growing Need of STEM Learning Kits & Homegrown Players. https://edtechreview.in/trends-insights/trends/4454-growing-needof-stem-learning-kits-homegrown-players.

[24]. National Program on Technology Enhanced Learning (NPTEL). http://nptel.ac.in. Workshop on Technology Enhanced Learning (WoTEL) documents are available at this site, as are other NPTEL project documents.

[25]. Massachusetts Institute of Technology Open Courseware (OCW) home page. http://ocw.mit.edu.

[26]. The National Mission on Education through Information and Communication Technology (NMEICT), Mission Document, Department of Higher Education; Ministry of Human Resource Development, Government of India: New Delhi, 2009; http://mhrd. gov.in/sites/upload_files/mhrd/files/upload_document/ MissionDocument.pdf.

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[27]. Virtual Labs. An Initiative of Ministry of Human Resource Development (MHRD) under the National Mission on Education through ICT; http://www.vlab.co.in/.

[28]. Downes, S.; Siemens, G. http://www.mooc.ca. (b) Invasion of the MOOCs: The Promise and Perils of Massive Open Online Courses; Krause, S. D., Lowe, C., Eds.; Parlor Press: Anderson, SC, 2014. http://en.wikipedia.org/wiki/Massive_ open_online_course.

[29]. Giri, S.; Dutta, P. Identifying Challenges and Opportunities in Teaching Chemistry Online in India amid COVID-19. J. Chem. Educ. 2021, 98 (2), 694−699.

[30]. Virtual Labs from India. Vlab: https://www.vlab.co.in, OLabs: http://www.olabs.edu.in.

[31]. Interdisciplinary Programme in Educational Technology (IDPET). https://www.et.iitb.ac.in.

[32]. Carnegie Mellon University, Department of Chemistry. The IrYdium Project. http://collective.chem.cmu.edu/pdf/UserGuide.pdf.

[33]. Carnegie Mellon University. Open Learning Initiative. http:// www.cmu.edu/oli.

[34]. Merrill, M. D. Instruction Strategies That Teach. http:// mdavidmerrill.com/Papers/InstructionalStrategiesThatTeach.pdf.