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Post-Colonial Agenda for Engineering Education Research in India

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Abstract

Context

India in 2020 announced the National Education Policy (NEP), which aimed at decolonizing and revamping all aspects of the education structure, including its regulation and governance. NEP 2020 was designed with the principle to nurture India's next generation into human beings who are capable of rational thought and action, who are compassionate and emphatic, who are courageous and resilient, and who possess scientific temper, creative imagination, and sound ethical values. Engineering education in India, therefore, is at a critical juncture to transform itself in alignment with the vision of NEP 2020.

Purpose or Goal

This work aims to systematically explore the existing efforts and future directions for aligning engineering education in India within the framework of the NEP. The broader goal of this study is to provide evidence-based suggestions to policymakers to establish a research agenda that helps engineering education align with the NEP 2020.

Methods

We employed a qualitative approach in the study and get the insights and perspectives of different stakeholders on critical challenges in Indian engineering education that need to be solved through research inquiry. To achieve this goal, semi-structured interviews were conducted with engineering education researchers, leaders, and practitioners in India, and the data were analyzed through thematic analysis to present the results in specific themes as they emerged from the data.

Outcomes

The results are reported through a proposed research agenda that is categorized into various themes identified to guide engineering education research in India along with specific questions that can be taken up for inquiry.

Conclusion

The NEP 2020 represents a crucial milestone in decolonizing the Indian education system, and engineering education must align with its vision. The findings from the study can guide engineering educators in India toward a systematic transformation of their education system.

Keywords—Engineering Education Research; National Education Policy (NEP) 2020; Research Agenda.

I. INTRODUCTION

India is now in its 77th year of independence and has since then taken a significant leap with respect to engineering education in the country. The set up of five Indian Institute of Technology (IITs) established in the period of 1951 to 1961, and sixth set up in 2001 helped establish quality of engineering education. Today, India is a home to more than 2500 engineering colleges producing approximately 1.5 million engineering graduates annually. A significant amount of this growth in engineering colleges can be attributed to liberalization. The liberalization of the Indian economy in 1991 led many multinational companies to enter the Indian markets. This coupled with the internet and software revolution a few years later led to a large number of IT services companies established in the country. The government's foresight to prepare India's youth for these emerging opportunities led to change in policies to allow privatization of higher education. India witnessed an exponential growth in number of engineering colleges since early 2000's, with most of them being affiliated to a local government-funded university, which prescribes the academic regulations, curriculum structure, course syllabus, and assessment process (Pratik et al., 2013).

However, the mushrooming of colleges across the country happened at the expense of good quality of education. The total number of colleges increased in engineering as the government established new institutions like the Indian Institutes of Information Technology (IIITs), as well as 23 IITs and 32 National Institute of Technologies (NITs), in an effort to produce a larger number of world-class engineers. Despite these efforts, they were still insufficient to meet the demand for technical and engineering education in India. The expansion of higher education took place along with loosely monitored regulatory systems that failed to put in check the necessary measures to ensure quality of education. As a result, many new engineering colleges began sprouting (table 1), many of which are private colleges monetizing education. Although some of them are accredited by All India Council for Technical Education (AICTE), or other bodies, many lack proper

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autonomy, quality infrastructure, have insufficient number of qualified faculty, and fail to equip students with required skills for employability in engineering. As reported by the "National Employability Report for Engineers 2019", 80% of these engineering graduates are not suitable for employment after graduation, as they lack the required technical and professional skills and mindset to work in the industry (Minds, 2019).

Table 1: Total No. of Universities in the Country offering engineering degree as on 25.01.2023

Universities	Total No.
State Universities	460
Deemed to be Universities	128
Central Universities	56
Private Universities	430
Total	1074

A major factor that impacts engineering education in India is outdated curriculum, taught through traditional teaching practices, and mostly assessed at the basic level of rote learning (Choudhury, 2016). Most of Indian education system focuses currently on the reproduction of knowledge which is long lasting imprint left by the British from their colonization of India for over two centuries. The Indian education system was originally designed by the British to create a subservient workforce. Since independence, its core principles have largely remained unchanged (Chaudhary, 2007). The Indian education system in the last many decades lacks avenues to prepare students for skills such as critical thinking, problem-solving, teamwork, communication, etc. The emphasis on rote learning continues to limit the learning capacity and development of Indian students even in engineering education, as most students are inadequately prepared to apply their technical knowledge to analyse and solve problems in the industry and society (Mohanty & Dash, 2016).

While curriculum reform, interdisciplinary education, teacher training, incorporating technology, and focus on soft skills seem to be increasingly discussed to change this situation, what is missing is systematic research reporting the effectiveness of such measures and identification of new measures that are needed and how they should be implemented. What factors have what effect, which factors need to be prioritized, and how various factors might be acting to make impact in India's engineering education, needs to be explored systematically using research. It's important to note that changes required to revamp India's engineering education quality cannot happen overnight and require a collective effort from educational institutions, government, industry, and society at large. However, with sustained effort, it's possible to transform the education system to better prepare students for the challenges of the 21st century. Thus, there is a need to identify research questions for transforming India's engineering education so that the education system can come out of the shackles of age-old processes, beliefs and systems. It is unique opportunity to deliver for the country's post-colonial engineering education needs by engagement of deliberations with all stakeholders including policy leaders, institutional decision makers, faculty, and students.

It is noteworthy to mention that India in 2020 announced in National Education Policy (NEP) which aims to produce engaged and productive citizens who would contribute to the development of an equitable, inclusive, and plural society as envisaged by our constitution (Kumar, 2021). NEP 2020 opens opportunities for engineering education in India to transform itself through systematic research, practice, and reflection on how Indian engineering students can be trained to think critically, solve problems, engage in higher-order and lifelong learning, develop care and empathy for the community, and communicate and work in teams to solve societal problems. However, effective implementation of NEP still requires work as each institute is figuring out their own ways to overcome challenges in engineering education. Research in this direction by engineering education researchers, will help create possible solutions to initiate the transformation of engineering education in India. This paper aims to empower engineering education researchers, India's practitioners, leaders, faculty, and policymakers for this transformation, by finding the right questions to focus on, through semi-structured interviews with stakeholders performed to discuss and deliberate a research agenda for post-colonial engineering education in India. Through various themes identified to guide engineering education research in India, and by formulating specific questions that can be taken up for inquiry, this paper seeks to provide the starting point that can be used to transform engineering education in India as envisioned by NEP 2020.

II. LITERATURE REVIEW

A. Pre-Colonial Education System in India

Higher education in pre-colonial India was characterized by a vibrant ecosystem of learning, intellectual exchange, and pursuit of knowledge across diverse disciplines. It nurtured a deep respect for wisdom, scholarship, and holistic development, providing a solid foundation for intellectual pursuits and the advancement of society. India had renowned centers of learning and universities such as Nalanda, Takshashila, Vikramashila, and Valabhi universities, which were instrumental in the dissemination of knowledge (Pandya, 2014). These institutions attracted scholars and students from across the Indian subcontinent and beyond, offering education in a wide range of disciplines. Indian higher education placed significant emphasis on the liberal arts and sciences. The curriculum covered diverse subjects such as philosophy, mathematics, science, astronomy, grammar, literature, music, and arts. This multidisciplinary approach aimed to cultivate a well-rounded education and foster critical thinking and intellectual development.

There was a great emphasis on holistic development of students as it aimed to nurture physical, intellectual, moral, and

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spiritual aspects (Tilak, 2020). Students were encouraged to cultivate virtues, practice self-discipline, and lead a balanced life as the goal was to create well-rounded individuals capable of contributing to society. Pre-colonial Indian education encouraged critical thinking, questioning, and independent inquiry (Crozet, 2012). Students were encouraged to debate, analyze, and interpret various texts and philosophical ideas to develop a deep understanding of the subject matter and promote intellectual growth. Overall, education in pre-British India emphasized spiritual, moral, and intellectual growth, aiming to produce individuals who were not only knowledgeable but also ethical and responsible members of society.

B. British Colonization of Indian Education System

During the British rule in India between 1858 and 1947, the education system underwent significant changes that reflected the colonial objectives and policies. The British introduced English education in India with the aim of creating a class of Indians who could serve as intermediaries between the British administration and the local population (Cohn, 2009). English became the medium of instruction in schools and colleges, and it was given more prominence than traditional Indian languages. The curriculum focused on English language proficiency and subjects relevant to colonial administration, such as law, administration, and engineering. The British administration showed little interest in promoting traditional Indian education systems and often viewed them as inferior (Ellis, 2020). Traditional educational institutions were marginalized and received little support from the colonial government. This led to a decline in traditional knowledge systems and practices. The British education system focused on promoting English literature, culture, and values, and the curriculum aimed to create a sense of admiration and loyalty towards British culture among the educated Indians. The education policies implemented by British were aligned with their colonial interests and the curriculum was designed to produce clerks, administrators, and professionals who could assist in the functioning of the British administration.
(Ghosh, 1993).

The British education system in India had several drawbacks and negative impacts on the country. The emphasis on English education and the imposition of Western values and cultural norms led to a disconnection from Indian cultural roots. Students were often alienated from their own traditions, languages, and heritage, resulting in cultural displacement and a sense of inferiority regarding their own culture and identity (Fischer-Tiné & Mann, 2004). The curriculum of the British education system had little relevance to the local Indian context. The subjects taught were often disconnected from the needs and realities of Indian society, failing to address the pressing issues and challenges faced by the people. The education system aimed to produce a class of Indians who could serve the interests of the British colonial administration, which hindered the development of independent thought and critical analysis among Indian students (Chaudhary, 2007). The British education system prioritized theoretical knowledge and academic subjects while neglecting vocational and practical education. This limited the development of practical skills and hindered the emergence of a skilled workforce capable of meeting the needs of the Indian society.

C. Review of Education Policies in India post-Independence

India achieved its Independence in 1947 and became a democratic republic a few years later when the Constitution of India came into effect on 26 January 1950. For the first two decades, education was given less of a priority by the Indian government, and little changes were made to decolonize the Indian education system. The most comprehensive education policy was first announced in the year 1968 and based on the recommendations of the Kothari Commission Report (Mukhopadhyay, 2017). One of the main focus of the National Education Policy (NEP) 1968 was to emphasize the need for universal primary education across the country especially to achieve national integration and social justice. The policy also provided a caution by highlighting the poor state of education across most schools and colleges due to lack of basic infrastructure and unavailability of skilled and passionate teachers. The next major education policy, the National Policy on Education (NPE) 1986, emphasized the need to provide equal opportunities to all in education as a way to reduce disparities and promote social justice (Majid & Kouser, 2020). The focus of NPE 1986 expanded its goal from universal primary education (as envisioned by the Kothari Commission Report) to secondary and tertiary education in India. The NPE 1986 also indicated the need to strengthen research in higher education. Multiple national and state research focused institutions were established to enhance research infrastructure in the country (Ramamurthy & Pandiyan, 2017).

D. De-Colonization of Indian Education System – the National Education Policy (NEP) 2020

India witnessed it first major intention to decolonize its education system from beliefs and influence of the British colonial rule with the announcement of the National Education Policy (NEP) in 2020 2020. Until NEP 2020, most of the previous education policies focused on improving the accessibility and quality of the education system that was mired by poor infrastructure and lack of skilled human resource (Rao, 2022). There were hardly any attempts made to fundamentally question the educational philosophy, the vision and aspirations of the education system, the local relevance of education curriculum, and the process followed teaching and assessment. The NEP 2020 was one of the first comprehensive policy framework to promote holistic development, foster creativity, and critical thinking skills and instill principles of ethics, empathy, and integrity among students (Kumar, 2021). It advocated for a flexible and multidisciplinary curriculum that allows students to choose from a wide range of subjects, encouraging a holistic and well-rounded education. The policy also aims to transform the assessment system to promote

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formative assessment and reduce the emphasis on rote learning (Malakar, 2022).

The NEP 2020 in its policy highlighted their intent to addresses many essential issues deeply rooted in the education system since post-independence (Jain et al., 2021). While the NEP 2020 incorporated certain elements from the ancient Indian education system, it is important to also note that it also took inspiration from global best practices to create a relevant and comprehensive policy for the modern educational landscape in India. The policy aims to build on India's rich educational heritage while also adapting to the changing needs of the 21st-century world. One of the major challenges expected in its successful implementation of NEP2020 is to critically examine and question colonial legacies, paradigms, and structures. Decolonization calls all stakeholders in the Indian education system to re-evaluate and restructure the curriculum, pedagogical approaches, and assessment practices to ensure they are inclusive, relevant, and representative of the local context.

In the last few years, higher education in India is undergoing several reformations in line with the recommendations of NEP 2020. However, successful transformation would require systemic disciplinary focused efforts from various stakeholders (teachers, students, parents, policymakers) to be involved in a dialogue to critically examine deeply rooted colonial influences on India's education system. As engineering is one of the most sought-after choices for higher education in India, we believe the transformation of engineering education should be led by research-driven inquiry to investigate and explore how the discipline can go through a post-colonial transformation by drawing the best from both ancient Indian systems and global practices. This research study aims to engage multiple stakeholders in the Indian engineering education ecosystem to examine, deliberate, and collectively suggest a post-colonial agenda for engineering education research in India. We believe such a research agenda will guide the systematic transformation of engineering education in India (Vijaylakshmi et al., 2022), in alignment with the vision and aspirations of NEP 2020.

III. METHODS

The authors employed a qualitative approach to address the research objectives of the study. Semi-structured interviews were conducted with the various stakeholders that play a key role in designing and implementing curricula at engineering. These stakeholders included engineering education leaders (i.e., deans and vice chancellors of engineering colleges and universities), heads of teaching and learning centers at engineering colleges, engineering education researchers and practitioners (i.e., people who either conduct research in engineering education or have been implementing research-informed pedagogies in classrooms). Cognitive interviews were conducted with few individuals to test the reliability of the semi-structured interview protocol and changes were made to a few questions based on the feedback received. A total of 18 participants (involving 6 engineering education leaders (EEL), 8 engineering education researchers (EER), 2 engineering education practitioners (EEP), and 2 heads of Teaching Learning Centers (TLC) were interviewed. It should be noted that all participants had some experience of working in the Indian engineering education context, i.e., they were working at an institution in India or, if they were employed by universities outside India, they had conducted research that directly pertained to issues related to engineering education in India. The interview questions asked participants about their prior experience with engineering education research and/or practice, current state of engineering education research in India, and their thoughts on the potential directions of research in this field. Prior to the start of each interview, verbal consent was taken from each participant for analyzing the data collected. The interview data were transcribed using Microsoft Teams' in-built transcription feature. The names of all the interview participants have been later anonymized during the data analysis process.

The transcribed interviews were qualitatively analyzed using the thematic analysis process (Braun & Clarke, 2006). The first step involved the authors reading through transcripts to identify instances where participants talked about either the challenges faced stakeholders in engineering teaching and learning or the potential directions for working in this space. This process involved inducting coding where each of the instances were assigned codes that were descriptive of the instance. In the next step, the authors explored the emergence of the themes by grouping the various inductive codes together. This step was an iterative process as different codes were grouped into different themes that described distinct potential areas for engineering education research in India. The analysis resulted in seven themes.

Trustworthiness was established during both steps of the analysis. The first step of assigning codes to interview excerpts was divided among the three authors. However, most interviews from this step were then reviewed by either one or both co-authors to identify points of disagreement. Each disagreement was resolved through discussions that resulted in the modification of the code. At the second stage of analysis that involved collapsing codes into themes, the authors again reviewed the final themes and the codes that were identified as part of a particular theme that were mutually agreed upon.

IV. FINDINGS

In this section, we present the themes that emerged from the data analysis. Exemplar quotes are provided as evidence for each theme. We provide pseudonyms (EER, EEL, EEP, and

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TLC) to all the participate and present their quotes by referring to the category of sample.

A. Theme 1 - Transformation of engineering curriculum based on the needs of the industry and society

Interviews with the participants revealed the growing need to transform the curriculum of engineering education in India and better align it with the local contexts. For example, EER1 emphasized the need to look at engineering education as a way to improve the socio-political aspects at both national and regional levels in India – *"Like the socio-political situation in India within a state, within a city, and within a town would be completely different. And so what can engineering education bring there? I think there's some kind of like assessment to make it contextualized, to make it community-based, would be really important."* This participant believed that it is important for engineering education to look inward, recognize local needs and problems, and empower engineering students with the knowledge and skills to address those problems in the society. Engaging students in meaningful experiences with the society has been reported significantly boost their preparation for personal and professional life after graduation (Kandakatla et al., 2023).

Another major transformation of engineering curriculum in India is required to increase its relevance to the needs of the industry. Engineering curriculum offered in most of the engineering institutions was designed several decades ago and is known to be outdated and irrelevant with the requirements of the industry. Participants believed there should be more extensive involvement and engagement of the industry in the design of engineering curricula so that the outgoing graduates are better prepared for their future roles. For example, EEL4 mentioned – *"I think that having industry involved in engineering curriculum setting and having a dialogue with them is very important? To let them know what we think and to accept what their requirements are, and find the middle ground is very important. This is an aspect of engineering education that we should look at seriously."* He indicated the need for the Indian government and associated policy makers to encourage autonomy and flexibility to adapt the curriculum with the continuous and rapid changes in the industry and how engineering institutions should explore different ways to integrate industry-oriented problems into the Indian curriculum.

B. Theme 2 - Adoption of evidence-based and student-centric teaching practices to enable higher-order learning.

One of the major post-colonial shifts needed in the Indian education system is to reduce the emphasis on rote learning in India. TLC 1 spoke in the interview about the continued emphasis on rote learning in India and need to promote original thinking which was at the core of Indian education system before the British colonization – "*One of the things I'm constantly reminded about in the context of India is the need to promoting original thinking. I can say analyzing we don't do enough of that. Encouraging and supporting questioning. And you know that that needs to be embedded back into the culture. I don't understand how we lost track of that tradition of questioning that we had always, but we need to bring that element into the fold and sort of move it, take it forward*". EEL2 spoke of the negative implications of the rote learning on development of the Indian students - "*Rote learning is something you know, which makes a child's brain limited*" and the TLC1 mentioned need to differentiate between surface and deep learning *"I have some superficial understanding of the subject just by reading through some things and I think that I have learned something. I think that is a very important topic for India to be able to understand between surface learning and deep learning."* EEL6 believed it is important to enable students to have learning opportunities think and engage at the higher-order cognitive levels - *"We need to really look at the pedagogy and the assessment to ensure that we consciously engage students in higher order learning. There need to be experiences where student need to solve open-ended problems."*

TLC1 encouraged the need for engineering faculty in India to build an understanding of evidence-based teaching and learning practices to enable students to engage in higher-order learning - "*We have to position the student in the context of solving a problem, work in teams as it needs to do critical thinking, problem solving, and you know all these things enable higher order thinking skills. If you refer to Bloom's Taxonomy, apply, analyze, evaluate, and create, those cognitive levels require one to be able to solve complex problems. You have pedagogies like PBL, service learning which essentially embed higher-order learning experiences*".

EEL3 emphasized a need for engineering education India to shift from teacher-centric to student-centric learning with a focus to improve students' motivation and increase their active engagement in the classroom "*Students need to be engaged in the class to promote higher level thinking. They should be made to think and express in the classroom. Because it's a 50-minute session and there are sixty such sessions in a semester. Each faculty member should at least spend a couple of classes where students are fully engaged through group discussions etc. How can we increase the number of faculty doing this?*"

Integration of experiential learning experiences in Indian engineering education was reported by EEL1 as another way to engage students in higher-order learning – "*Lots of experiential learning with problem-based learning approach. There are many approaches which we can learn and bring into the practice to ensure higher order learning*". He further elaborated the need to understand how and to what extent experiential learning can be embedded into students learning experiences – "*How we can bring in more experiential, contextual, situated learning into our student experiences? How pedagogy can be designed to challenge the student?*" EEL3 also emphasized that

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the assessment practices followed in Indian engineering education must also be aligned to evaluate higher-order learning, which would require a paradigm shift in how Indian educators perceive the purpose and value of assessment in educational process. As she noted – "*How do Indian students learn? That's an interesting question at a broad level because we have so much of this emphasis on exams, marks, coaching, etc. Do they really assess learning of students? And if so, how much of it is happening? So, I think those are all important questions to answer*". EEP1 also mentioned the need to increase focus formative assessment to provide students feedback on their learning "*There are so many exams that are held and assessments that are done. What is the quality of the feedback that is given to the student and how many students get that personalized feedback? We don't know. But there is a way, through formative assessments, how do you increase that?*". Evidence-based assessment methods must therefore be explored, analyzed, and adopted in the Indian context.

C. Theme 3 - Breaking disciplinary boundaries to promote inter and multidisciplinary engineering.

EEL6 recognized that industry in the current contexts require engineering professional to work on problems which are multidisciplinary in nature thereby emphasizing its importance among engineering graduates *"Complex problems of today's world cannot be solved by disciplinary knowledge alone. While the way I understand that the purpose of higher education is to equip the learners with disciplinary competencies, we need to also focus on students' ability to work in multidisciplinary teams to solve the problems, of today's world. So, these are the perspectives through which we need to look at multidisciplinary education and its need in the context of engineering education"*. The boundaries between engineering disciplines are converging in the modern context "*Disciplinary boundaries are blurring as today's complex problems require multidisciplinary skills*" and academic institutions must therefore evolve from the existing disciplinary silos. EEL1 said "*How the traditional institutions which have lived for a very long time in silos, an engineering institution, a law institution, a liberal arts institution, a science institution, must now break their boundaries, develop capability to bring multidisciplinary experience. Because I think the way forward, not just for engineering education but for higher education in general is to break down silos*."

As there is a shift towards inter and multidisciplinary learning, there is also a need for exploring innovative approaches to embed multidisciplinary learning experiences among students (Amashi et al., 2021). EEL6 said there is a lack of understanding currently on how multidisciplinary learning as a concept can be put to practice – "*We need to really understand multidisciplinary [learning]. How we can bring multidisciplinary learning into our curriculum. We are not yet very clear about it. [A] lot of research needs to happen in Indian context. It needs to be embedded strategically and we still are not very clear on how. There is lot of literature but in Indian context, these experiments need to happen*". Similarly, EER3 also discussed about interdisciplinarity as an approach to provide students with varied career pathways after graduation "*I always thought that it probably, you know, it would help to have more interdisciplinary approach for students who want to probably explore other new areas to do something that they want to do*."

D. Theme 4 - Reimagining engineering education through technology

Participants believed it is important reimagine engineering education using technology, so that engineering educators can understand the different ways in which technology can serve as an enabler (Deepika et al., 2021). The sudden shift to online learning due to the disruptions caused by COVID19 pandemic in India has opened avenues to experiment with technology in engineering education (Syed et al., 2021). One of the prominent approaches recommended by participants was blended learning, which combines both classroom and online learning (Kandakatla et al., 2020). Through technology tools, students can now have access to learning resources from renowned faculty both inside and outside of their institutions (Kandakatla et al., n.d.). EEL5 said - "*You can have blended learning and learn online. For us as educational institutes, the best professors can record their lecture and all interested students can learn from them. Because everyone cannot get admission in the premier institutions which have the best faculty. However, I can access some of their teachings through technology*". TLC2 mentioned how the use of technology could provide opportunities for engineering institutions in low resource contexts to engage their students in experiential learning through virtual labs – "*Most engineering schools in India are suffer from lack of infrastructure. They don't really have good laboratories. So virtual labs could be a really good complement for actual experience*." How does specific technology affect or change engineering education in India, should also be studied.

Participants noted the tremendous potential of emerging technologies such as Artificial Intelligence (AI), Augmented Reality (AR), and Virtual Reality (VR) and reflected on how they could be integrated into engineering education in India. EEL5 noted the advances in AI on it could disrupt current practices in engineering education – "*The way AI is penetrating the system, the way data analytics is maturing, I'm very sure we will have well informed approaches on self-regulation and self-motivation of learners [and] support for the teacher in engaging the learner effectively in the teaching learning process through the use of AI technologies*". EER6 mentioned opportunities for research in the use of generative AI tools in engineering education – *"a lot of research required at how AI and ChatGPT is being used for engineering education*". EEL1 indicated other emerging technologies like AR and VR to have huge scope for engineering education in India as they provide opportunities to simulate industry setting in the engineering

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institutions – "*You know AR, VR kind of environment or metaverse kind of environment will be a good surrogate for real hands-on work. This requires quite a bit of research to understand students can experiment in such virtual environment.*"

E. Theme 5 – Nurturing innovation and entrepreneurship for self-reliant India

The COVID19 pandemic has pushed governments across the globe to recognize the important of robust supply chains that are self-reliant in terms of consumption and production in the country (Kandakatla et al., 2021). EEL6 believed innovation and entrepreneurial efforts in India must be aligned to the local needs of the diverse population in India – "*how can typical Indian institution particularly in Tier 2, Tier 3 cities can build an innovation and entrepreneurial ecosystem. To drive innovation and entrepreneurial ecosystem, we must understand that each of us should influence the socioeconomic scenario of the region in which we live. Where our institutions are present, we need to go beyond teaching and research and should participate in a transformation of the region. For us to play that role, we need to find that model of driving innovation and entrepreneurship.*" EER1 said there is immense potential for entrepreneurship in India if we're able to embed innovation thinking and mindset among the upcoming younger generation – "*It's about the mindset. So, in that sense to me it's absolutely important, at least for a country like India where it's a huge country with diverse culture, and one size does not fit all here. Our engineering education system should formally recognize the importance of both innovation and entrepreneurship and create adequate space in our curricular settings to promote and formally rewarded students. Then it becomes part of one's DNA.*"

However, the nurturing of innovation and entrepreneurship in engineering institutions requires a complete ecosystem. EEL1 noted, "*You see, innovation and entrepreneurship need an ecosystem. It does not come from one of subject on innovation or one of subject on entrepreneurship. The institutional ecosystem is very essential. For you to drive innovation, the first question we need to ask is how? Learning experience in our institution that challenges the student to solve the real problems, to connect to the real world. Because always the innovation happens when we connect to the real world and understand the issues and challenges through observation, through engagement. Without that, innovation does not happen just like that. So how well can we engage our students to with the larger ecosystem which really challenges him*". EEL3 said the ecosystem should also align student's innovative ideas with entrepreneurial knowledge "*How well our ecosystem helps them to move forward by making them to build his own solution process and see whether this problem is a business opportunity or this problem has a greater social impact, or it has both. So, all these things we need to build without building the required ecosystem in the institution.*"

F. Theme 6 – Role of faculty as change agents in the transformation of engineering education

Engineering faculty in India are considered as one of the key stakeholders as they're the change agents who will lead the transformation of engineering education. EEL6 said – "*You know, to me, one of the major concerns is the teacher. He is the change agent. So how do I enhance the productivity of the teacher in the field? Everything that you do, you know, all issues related to teachers are to me absolutely important because they are the change agents. So, to me, engineering, education, research, focusing on the changing role of the teachers in today's context, the challenges that they have, how do we empower them? How do we keep him on the pedestal of learner? So that he continues to learn and thereby continues to contribute to the engineering education space"*. However, the EEL3 considers a change in engineering faculty beliefs and mindset as one of the major challenges that could impede any transformation – "*Transformation of faculty toughest because most of us teachers, we come from a legacy. We have our own practices, 30-40 years of our experiences have shaped us in a particular way. I mean particular way of working, particular way of thinking. NEP 2020 really challenges us. It wants a very different approach from us. How well can we transform ourselves at individual level*".

EEL6 believed there is growing acceptance among Indian faculty on the change in expectations from Indian engineering institutions – "*But today I'm seeing there is a growing recognition among engineering educators themselves that. They also need to know pedagogical skills they need to have. They also need to be aware of technological skills, you know, so disciplinary knowledge, pedagogical skills and technological awareness.*" However, large scale capacity building efforts needs to be taken up to change the beliefs of faculty from being present in the past to being futuristic "*I think it will have really positive impact if faculty are able to understand why it is done that. Any old institution will have a heterogeneity of faculty who are very seniors, who are in the middle, who are the youngsters. So how do you manage these people in getting them trained? Because generally we will be talking about the past only, but we should come out from that past, talk about present in the future.*" The use of faculty development programs and communities of practice have been reported to enable large scale change among faculty towards their instructional practices (Kandakatla & Palla, 2020). TLC1 reported how faculty should be instilled with feelings of care towards students – "*I think is very important that faculty are curious and empathetic enough that they want to see their student do well. Am I able to mentor students throughout the four years because I have a personal interest in their growth?*"

G. Theme 7 – Change in engineering students' attitudes, aspirations, and learning preferences.

The last theme of the study focused another important and the most essential stakeholder that is the engineering students. Engineering is the one of most sought-after discipline for higher

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education in India, with over a million students graduating every year. EEL2 said majority of the students often lack the interest and motivation as most of them join engineering education due to parental or peer pressure "*We have many students who have joined a relevant branch not with their interest but because of parental and peer pressure*". TLC1 believed students motivation in classroom as a major challenge - "*Motivation is a big part of it, but how do you bring day-to-day classroom? So there's a 50 hours of classroom. How much time and how many students are attentive? So what is the connection between attention and so more into the ability to self-regulate the mind and be focused? Of course meditation is an important part of our culture and it is, but it's not perceived like that among the students. So it is, it is an important aspect because attention is a big problem today*."

The current students who are part of the GenZ (students born in and after early 2000s) particularly have challenges with low attention span and engagement in the classroom. EEL4 believes engineering institutions must therefore explore innovative methods to engage with these learners - "*Handling GenZ students is not so easy according to me. It needs a different kind of pedagogy because the retention rates are very, very less. They're all born with a mobile phone. A lot of innovation is required, lot of education research is required for us to understand how exactly all these dimensions can be brought into the student experience as per the unique aspirations*." EEL5 emphasized the need to encourage self-regulated learning among students, to help them become life-long learners and keep up with the rapid changes in the industry – "*Another change that I foresee is, no skill will stay beyond the three to five years with anybody. If you want to remain valid, you must upgrade yourself. So lifelong learning is going to be a major thing probably in one's lifetime. One will have to visit, you know, institutions multiple times to reskill and upskill himself, you know*." EER2 said efforts must also be taken to instill compassion, ethics, and empathy among students with a goal to make them socially responsible - "*So we have to train our students in that way in the four years they are with us, they learn about sustainability, SDGS, ethics etc. I think those are the changes which must be taken in into account when we are actually nurturing students into good human beings*".

V. DISCUSSION

We now present a research agenda for engineering education in India through various focus areas along some guiding requestions for engineering education researchers in India. It is important to note that while some of the research questions proposed were directly suggested by the participants (specifically the engineering education researchers), the other research questions are being proposed by the authors (as engineering education researchers themselves) based on the themes and discussions presented in the results section.

A. Discipline-based educational research

- How can student-centered teaching and learning practices be adopted to address issues of motivation, attention, and retention among GenZ learners?
- What evidence-based teaching practices and assessment methods could be designed to engage Indian engineering students in higher-order learning?
- How can the horizontal and vertical alignment of engineering curriculum be improved in India?
- What are the disciple-specific skills expected from Indian engineering graduates to overcome the barriers of transition to workspace?
- How can discipline-specific collaborations models could be implemented in engineering institutions to bridge the gap between industry and academia?

B. Multidisciplinary engineering

- What models of experiential learning can be adopted by Indian engineering institutions to promote multidisciplinary learning?
- How can strategic collaborations be established among different disciplines in an institution to promote multidisciplinary engineering?
- How can students be provided with informal opportunities to engage in multidisciplinary learning experiences?
- What skills are required by engineering faculty to engage students in multidisciplinary learning experiences?
- How can computer science be integrated into core engineering disciplines (civil, electrical, and mechanical) to improve students' interest and align with needs of the industry 4.0?

C. Technology-enhanced Learning

- How can blended learning be adopted in Indian engineering institutions to promote student engagement and learning outside the classroom?
- How can virtual laboratories be used to provide students with experiential learning opportunities especially in low resource contexts?
- How can data analytics be used to assess individual learning needs, preferences,
- How can AR/VR be developed and embedded to provide engineering students with authentic learning experiences?
- How can artificial intelligence based used to predict the enablers and barriers in the learning pathways of engineering students?

D. Community engagement through Service-Learning

- How can the engineering curriculum be localized to the needs of the Indian society?

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- How can Indian engineering graduates be nurtured into ethical, empathetic, and socially responsible citizens of the country?
- How can engineering institutions increase the relevance towards the socio-economic development of nearby regions?
- What are the enablers and barriers for engineering faculty and students to engage in service-learning?

E. Innovation and Entrepreneurship in Engineering Education

- How can engineering students be engaged in design and development of innovations through curricular and in-formal learning experiences?
- How can entrepreneurial thinking be nurtured among engineering students in India?
- What are the effective models engineering institutions foster an ecosystem for innovation and entrepreneurship?
- What are the formal and in-formal mode for engineering faculty to engage in innovation and entrepreneurship?
- How can entrepreneurial mindset be inculcated among engineering faculty to increase potential for monetization of research activities?

F. Facilitating Change in Engineering Institutions

- What are the barriers to change among engineering institutions to transform themselves in line with recommendations of NEP2020?
- How can engineering faculty in India be supported towards the pedagogical transformation of their classroom practices?
- How can engineering faculty's perceptions of assessment be changed to encourage increase in use of formative practices?
- How can engineering faculty be inculcated with feelings of care and compassion towards the holistic development of their students?
- How can engineering faculty and students in India be enabled to become life-long learners?
- What models can engineering institutions adopt to promote diversity and inclusion among their stakeholders?

VI. CONCLUSION

Research in engineering education in India can transform our education, bringing students out of rote learning mode and inbreeding innovative mindset and ownership of learning. It is necessary to change faculty and institutional landscape and mindset for shaping today's engineers, and furthermore mould our thought processes to deliver the quality of education with intentionality for preparing the workforce and tomorrow's leaders capable of addressing post-colonial India's grand challenges. The research agenda presented in this study is an attempt to guide engineering education researchers to answer critical questions that are essential to be answered for post-colonial transformation of engineering education in India.

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