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Research Article

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Model for Facilitative Practical Learning in Engineering Education Under India's New Education Policy (NEP): A Stepwise Framework

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ARTICLE INFO	ABSTRACT

Engineering education stands as the linchpin of any advanced society. The onus of nurturing highly skilled technocrats, primed to yield tangible outputs, lies squarely with educational institutions. Engineering, inherently an embodiment of applied science, mandates engineers to wield scientific principles adeptly in resolving societal, industrial, and national quandaries. Presently, industries find themselves compelled to furnish engineers with supplementary training to bolster their efficacy and productivity. This paper undertakes an exploratory journey into a suggestive methodology, which advocates for the integration of innovative experimental techniques into engineering education with reference to NEP2020 suggested by government of India. It endeavors to juxtapose the conventional model of engineering practical education against the proposed paradigm, which endeavors to kindle intuitive cogitation, analytical acumen, and problem-solving prowess among technocrats. Additionally, the paper scrutinizes the facets of skill development and delineates the merits and demerits inherent in both educational systems.

Keyword: *Traditional System, NEP, Experiments, Skill Development, Instructional Learning.*

1. Introduction

The pivotal role of engineering education in driving a nation's development is widely acknowledged. Numerous illuminating examples from countries such as China and Japan underscore the significance of a robust technical foundation in shaping global economic landscapes. These nations, owing to their formidable technical prowess, have secured substantial shares of the global economy. India, although positioned similarly, lags behind in certain technical spheres. Consequently, penetrating a highly dynamic market becomes a formidable challenge if the workforce being trained lacks comprehensive knowledge and expertise. Herein lies the critical role of technical education, where the Government of India is spearheading numerous initiatives aimed at enhancing this sector. Substantial funds are allocated, designated either as capital or infrastructural funds, with the explicit aim of transforming the prevailing scenario.

The current landscape reveals approximately 3,384 institutes dedicated to technical (engineering) education, catering to a staggering population of 1,634,596 students, approximately 17 million. Furthermore, there are 63,430 students pursuing post-graduate education in this field. Despite the commendable efforts undertaken by the government to bolster technical education, industries continue to encounter challenges in integrating freshly graduated engineers into their workforce seamlessly. These engineers often lack the requisite productivity and efficiency from the onset, necessitating additional training and development initiatives by industries. This presents a significant hurdle in technical education - the imperative task of preparing manpower to be productive. The primary culprit lies within the educational paradigm itself. The prevailing system of engineering education exhibits certain drawbacks. Under this system, the predominant emphasis is placed on classroom instruction, commonly referred to as classroom teaching. Practical education, which involves students substantiating theoretical concepts through hands-on experimentation, is relegated to a secondary position within the curriculum. [1]

In this context, a significant portion of institutes faces a dual challenge: either they lack adequate instrumentation, or even if available, students are deprived of opportunities to engage in practical experimentation. Consequently, students are confined to theoretical learning, devoid of the invaluable experience gained through practical application. This underscores the pressing need to examine the current educational system and the demands it imposes.

2. NEP in Technical Education - India

The National Education Policy (NEP) in India encompasses reforms and guidelines aimed at transforming various aspects of the education sector, including engineering education. The NEP 2020, a landmark policy document, emphasizes a holistic approach to education, with a focus on fostering critical thinking, creativity, and innovation among students. In the context of engineering education, the NEP emphasizes several key aspects: [2]

1. Interdisciplinary Learning: Encouraging interdisciplinary approaches to education, breaking down silos between different branches of engineering and integrating them with other disciplines such as humanities, social sciences, and management.
2. Flexibility and Choice: Providing students with flexibility in choosing their courses and the option to pursue minors, dual degrees, or interdisciplinary programs alongside their core engineering curriculum.
3. Experiential Learning: Promoting hands-on, experiential learning opportunities through internships, industry collaborations, and project-based courses to bridge the gap between theoretical knowledge and practical application.
4. Focus on Research and Innovation: Fostering a culture of research and innovation within engineering institutions, encouraging faculty and students to engage in cutting-edge research and entrepreneurial activities.
5. Teacher Training and Professional Development: Enhancing the quality of engineering education by investing in teacher training programs, curriculum development, and continuous professional development initiatives for faculty members.
6. Promotion of Indigenous Knowledge and Technologies: Recognizing the importance of indigenous knowledge systems and technologies, integrating them into the engineering curriculum to address local challenges and foster sustainable development.
7. Emphasis on Ethics and Values: Incorporating ethics, sustainability, and social responsibility into engineering education to produce ethically conscious and socially responsible engineers.
8. Digitalization and Technology Integration: Leveraging digital technologies and online platforms to enhance learning outcomes, promote remote education, and expand access to quality engineering education across diverse geographical regions. (Fig 1)

Overall, the NEP aims to revitalize engineering education in India by promoting innovation, inclusivity, and excellence, thereby equipping graduates with the skills and knowledge needed to thrive in a rapidly evolving global landscape. [3]

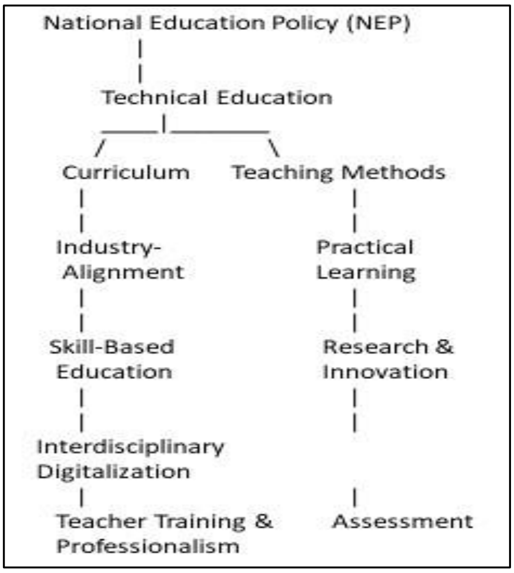

Figure 1 : NEP flow

Present case study

In delineating technical education, it is commonly understood to comprise two integral components: classroom instruction and practical application. However, within this framework, disproportionate attention is often directed solely towards classroom teaching. To elucidate this point, let us examine the syllabi of Mechanical Engineering offered by two sample Universities as case studies. (Figure 2)

Subject Code	Subject Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract.	Theory	Pract.	Total
MEC501	I C Engines &	4	2	4	1	5
MEC502	Mechanical Measurements and Control	4	2	4	1	5
MEC503	Production Process-III &	4	2	4	1	5
MEC504	Theory of Machines- II&	4	2	4	1	5
MEC505	Heat Transfer &	4	2	4	1	5
MEL5O1	Business Communication and Ethics #	-	2$+2	-	2	2
	Total	20	14	20	7	27

Figure 2: A Sample number one from university

Code	Subject	Teaching Scheme (Weekly Load in hrs)			Examination Scheme (Marks)					
		Lect.	Tut	Pract.	Theory		TW	PR	OR	Total
					In Sem.	End Sem.				
302041	Design of Machine Elements – I	4	--	2	30#	70@	25**	--	--	125
302042	Heat Transfer	4	--	2	30	70	--	50*	--	150
302043	Theory of Machines-II	4	--	2	30	70	--	--	50$	150
302044	Metrology and Quality Control	3	--	2	30	70	--	--	50	150
302045	Hydraulics and Pneumatics	3	--	2	30	70	25	--	--	125
302046	Skill Development	--	--	2	--	--	50	--	--	50
Total of Semester – I		18	--	12	150	350	100	50	100	750

Figure 3: A Sample number two from University

The structures itself (Figure 3) show that the major focus is on the theory teaching as compared to practical learning. The drawback lies here that the students are not trained sufficiently. But Technical Authority has its own structure and Technical Authority structure is entirely different. This highlights a common issue in educational systems where there's a perceived imbalance between theoretical teaching and practical learning. This disparity often results in students not being adequately prepared for real-world applications of their knowledge and skills. The mention of Technical Authority suggests a regulatory body responsible for overseeing technical education in India. Technical Authority sets standards and guidelines for technical education institutions, including curriculum design, faculty qualifications, and infrastructure requirements. However, the paragraph suggests that despite Technical Authority's regulatory efforts, there remains a notable emphasis on theoretical teaching within educational structures. The mention of Technical Authority could imply a comparison between different educational systems or structures, perhaps at regional or institutional levels. This comparison underscores the variability in educational approaches and priorities, which can contribute to disparities in the balance between theory and practice. [4]

Overall, it suggests that while Technical Authority and similar regulatory bodies may provide guidelines for technical education, there can still be significant differences in how these guidelines are interpreted and implemented at various levels. This can result in systemic issues such as insufficient practical training for students, highlighting the need for ongoing evaluation and adjustment of educational structures to better align with the needs of students and the demands of the workforce. [3]

3. Technical Authority Requirements

Technical Authority has set its own structure in order to attain balance between class room teaching and practical learning wherein the skill and abilities development has been well considered. The Technical Authority approach to engineering and Technology education is stated as a major objective of education in India now is to develop technical professionals having competencies, intellectual skills and knowledge

equipping them to contribute to the society through productive and satisfying careers as innovators, decision makers and leaders in the national and global economies of the 21st century, the Approach to Curriculum for UG Degree Programs needs to lay special emphasis on educating/preparing the students well for being able to demonstrate the following abilities:
The abilities are listed as follows:
(a) Proficient application of mathematical, scientific, and technical principles;
(b) Strategic planning and meticulous design for conducting experiments in scientific and technical realms;
(c) Comprehensive analysis and insightful interpretation of data collected from scientific, technical, and economic sources;
(d) Crafting parts, subsystems, systems, or processes tailored to specific requirements;
(e) Proficiency in identifying, formulating, and resolving problems utilizing simulation or other methodologies;
(f) Mastery of diverse techniques and tools, including software applications across all fields, as necessitated;
(g) Effective communication prowess and adept leadership or participation within team dynamics;
(h) Adherence to professional standards, while fulfilling social and ethical obligations; (i) Sensitivity towards environmental and energy-related issues and their implications; (j) Strategic planning, development, and execution of lifelong learning strategies.

This balanced structure helps to attain the objectives stated by standard setters and these objectives are:
1) Readiness: Our aim is to equip students with the necessary skills to excel in diverse educational programs or to thrive in technical professions within various industries, through further education and training opportunities.
2) Foundational Competence: We strive to impart a strong grounding in mathematical, scientific, and engineering fundamentals, essential for tackling challenges within the engineering and technology domain.
3) Comprehensive Understanding: Our focus is on providing students with a wide-ranging knowledge base in science and engineering, enabling them to comprehend, analyze, and innovate solutions for realworld problems.
4) Professionalism: We emphasize the development of a professional and ethical mindset among students, fostering effective teamwork, a multidisciplinary approach, and the ability to contextualize engineering and technology issues within broader societal frameworks.
5) Nurturing Environment: We are committed to fostering an academic environment characterized by excellence, leadership, ethical standards, and a culture of lifelong learning, essential for nurturing sustained and fulfilling careers.

The present system being employed is running in opposite direction in total. If we look at the present system of imparting practical education which is the need for Engineering and technology, then it would disappoint us really.

4. Present Practical Education System

Majority of Institutes dealing with engineering and technology education follow the conventional method of imparting practical knowledge. The conventional or traditional method comprises of following major steps:
1. Theory Instruction: Theoretical concepts are presented in a classroom setting accommodating approximately 70 students or more, with an emphasis on elucidating fundamental principles.
2. Experimental Setup Explanation: The experimental apparatus and test rig are detailed to groups of 20 or more students simultaneously, providing insight into the procedures to be conducted.
3. Experiment Execution in Cohorts: Following comprehensive instructions, laboratory assistants facilitate the execution of experiments, with some students tasked with recording pertinent data.
4. Calculation and Analysis in Groups: Subsequent to data collection, calculations and analyses are performed collectively in groups.
5. Data Representation: Results are graphically depicted to visually represent the outcomes of the experiments.
6. Conclusion Formulation: By following the aforementioned steps, students draw conclusions affirming the validation of the fundamental principles under examination.

This way the experimental teaching gets over. There are many drawbacks of this system.

5. Drawback of Conventional Practical Education System

The conventional system is although fit for semester type of system as the curriculum completion is time bounded. It comes along with several disadvantages like:

1. Absence of Autodidactic Opportunities: The educational framework lacks provisions for self-directed learning, operating under a one-way communication model where students passively receive information without practical engagement.
2. Discouragement of Intuitive Thinking: There is minimal encouragement for students to cultivate intuitive thinking abilities, stifling their capacity for innovative problem-solving.
3. Lack of Industry Relevance: The curriculum fails to foster an appreciation for the practical skills required in the market, with students remaining oblivious to the intricacies involved in developing experimental test rigs.
4. Passive Learning Paradigm: Students predominantly adopt a passive stance, merely observing and attempting to comprehend concepts solely based on classroom instruction, devoid of hands-on application.
5. Limited Access to Resources: The batch-oriented approach impedes equal access to experimental setups, restricting students' opportunities to closely interact with and manipulate the test rigs.
6. Teacher-Centric Learning Dynamics: The prevailing educational model prioritizes teacher-led instruction, neglecting to assess individual competencies and consequently constraining personal growth.
7. Superficial Conceptual Grasp: Due to the aforementioned limitations, students may exhibit superficial familiarity with concepts without truly grasping their underlying principles and applications.
8. Plagiaristic Practices: A copy-and-paste mentality prevails among students, who resort to duplicating content from previous years' journals and readings, undermining genuine learning and intellectual development.

Here is the need and scope for improvement. We suggest a method to improve the practical learning experience in time bound curriculum.

6. Proposed System- Practical Learning

Taking into consideration all the drawbacks of the conventional system we propose here a system where the students will learn on their own and will find out the way to understand the concept or fundamental principle that they have learnt in class room teaching. The proposed method is a guided freedom effort taken by students to arrive to the conclusion in their own way by the method suggested and developed by them. The steps to be taken for implementation of the system are:

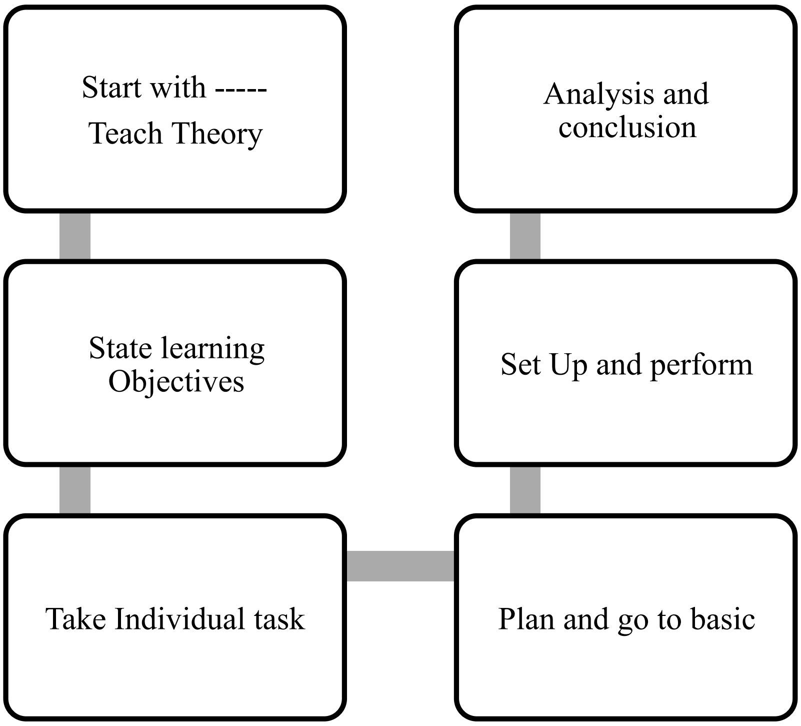

Figure 4: Stepwise process to be followed

The proposed system is comprised of following formula to arrive at the results required. (Fig. 4)

Step 1: Theory Instruction - Traditional classroom teaching is employed to impart theoretical concepts to students, providing them with foundational knowledge.

Step 2: Objective Formulation - Following theory instruction, students are tasked with defining the objectives of their study. This step encourages the development of reasoning skills as students articulate the purpose of proving the learned principles.
Step 3: Individual or Group Task Assignment - Depending on the complexity of the experiment, students are assigned individual or group tasks aimed at proving the stated objectives. This phase fosters creativity as students devise various approaches to validate the principles, thereby testing their scientific application and design capabilities.
Step 4: Setup Preparation - Students proceed to sketch and prepare the experimental test rig required to fulfill the stated objectives. This stage involves planning and execution, nurturing students' ability to strategize and implement plans effectively.
Step 5: Experimentation - Armed with their designed setups or modifications to existing facilities, students conduct the experiment as per their devised procedures, putting their theoretical knowledge into practical application.
Step 6: Analysis - Following data collection from the experiment, students analyze the results through calculations and graphical representation. This step enhances their analytical abilities as they interpret findings and draw conclusions. If results are inconclusive, students revisit the process from Step 1 to Step 5, iterating until satisfactory outcomes are achieved.

This innovative approach encourages active learning, fosters critical thinking, and nurtures problem solving skills among students, equipping them with the practical experience and analytical prowess necessary for success in their academic and professional pursuits.

7. Advantages and Challenges

Advantages

- Self-learning Empowerment: Through the Step Formula, students are empowered to engage in self-directed learning, fostering autonomy and responsibility in their educational journey.
- Promotion of Intuitive Thinking: The approach encourages students to rely on intuitive thinking to devise solutions and address challenges, nurturing their creativity and problem-solving skills.
- Development of Market Skills: By actively participating in the development process, students inherently develop market-relevant skills, gaining insights into product development, market dynamics, and consumer needs.
- Strengthening Decision Making and Planning: Students are prompted to make decisions and plan effectively as they navigate the process of proving and solving problems, honing their decision-making abilities and strategic planning skills.
- Improvement in Planning and Implementation: The approach emphasizes the importance of planning and executing plans, providing students with practical experience and opportunities to refine their planning and implementation skills.
- Inclusive Learning Environment: Every student is afforded the opportunity to perform and learn, fostering an inclusive environment where diverse ideas and perspectives are valued and encouraged.
- Student-Centered Learning Approach: Contrasting with traditional methods, this approach places students at the center of the learning process, prioritizing their active participation, exploration, and discovery.
- Enhanced Conceptual Understanding: Through hands-on experimentation and problem-solving, students gain a deeper understanding of engineering concepts, reinforcing theoretical knowledge with practical application.
- Share and Learn Philosophy: The method encourages a collaborative "share and learn" ethos, where students exchange ideas, insights, and experiences, fostering a dynamic learning community and discouraging the passive "copy-paste" approach.

Challenges:

- Time Constraints of Curriculum: Adherence to a time-bound curriculum poses a significant challenge, as it requires balancing syllabus completion, practical exercises, and other activities within predetermined timeframes.
- Availability of Infrastructure: Adequate infrastructural facilities within the college are essential to support hands-on learning experiences, necessitating investment in resources such as laboratories, equipment, and workshops.
- Faculty Engagement and Enthusiasm: Overcoming resistance to change and garnering enthusiastic support from faculty members is crucial, as embracing unconventional teaching methods may initially encounter skepticism and resistance.
- Class Size Considerations: Managing larger class sizes presents challenges, particularly with the increasing intake mentality of management, which can strain resources and impact the effectiveness of individualized learning experiences.

- Balancing Subject and Practical Workloads: Addressing the volume of subjects and practical exercises within the curriculum requires careful planning and flexibility to adjust objectives and expectations based on workload and resource availability.
- Support from Management: Successfully implementing innovative teaching methodologies relies on the willingness and support of management, particularly in private institutions where decision-making may be influenced by financial considerations and institutional priorities.

Navigating these challenges necessitates collaboration, flexibility, and commitment from all stakeholders, including faculty, management, and students, to create an environment conducive to effective hands-on learning and experimentation.

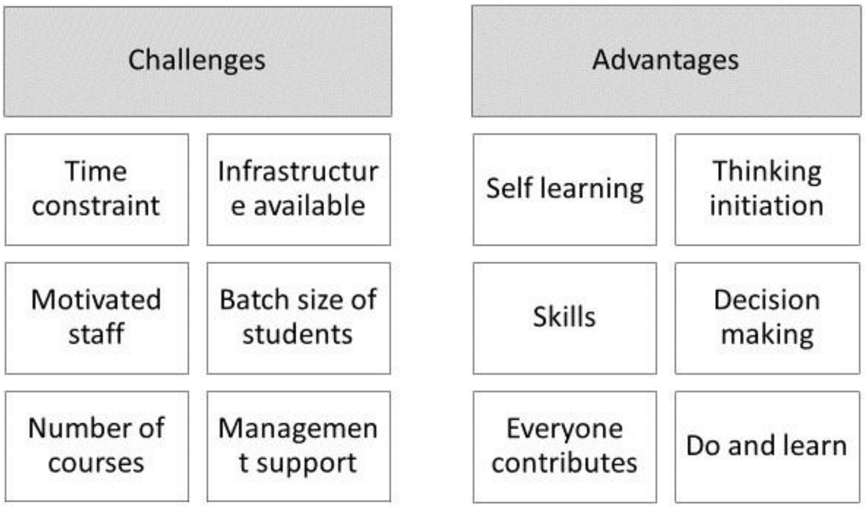

Figure 5: Advantages and Challenges

If we can work with the said challenges and solutions are seek some of the major challenges the proposed steps can provide us solution to make the engineers ready to be productive from day one. Figure 5

8. Conclusion

It is proposed a set of steps or a methodology called "Step wise framework " (SWF) to address the attributes of self-learning, reasoning, planning, implementation, analytical thinking, and problem-solving in engineering education. Let's break down your proposed solution and its potential implications:

1. Following curriculum limits and checking usefulness: This suggests a review of the current curriculum to ensure it aligns with the desired outcomes of fostering self-learning, reasoning, planning, and problem-solving abilities. By setting aside dedicated time on weekends to evaluate the effectiveness of teaching methods, educators can iteratively improve the curriculum.
2. Appealing to try the "NSF" method: Encouraging educators and students to adopt the NSF method for at least one subject implies a pilot program to test its efficacy. This allows for practical assessment and feedback to refine the approach before broader implementation.
3. Creating small incubation centers for each lab: Establishing small incubation centers within labs can promote hands-on, experiential learning. These centers could serve as hubs for collaborative problem solving, experimentation, and innovation.
4. Assigning mini-projects: Integrating mini-projects into the curriculum provides students with opportunities to apply theoretical knowledge in practical scenarios. These projects can enhance analytical thinking, planning, and implementation abilities while fostering creativity and initiative.
5. Reducing batch size: Smaller class sizes enable more personalized attention and interaction between students and educators. This can facilitate better understanding of concepts, increased engagement, and more effective implementation of teaching strategies.
6. Guided freedom in experiment selection: Granting students guided freedom to choose experiments fosters autonomy and ownership of learning. It encourages exploration, critical thinking, and decisionmaking while ensuring alignment with learning objectives.

Implementing these steps requires careful planning, resources, and support from educational institutions. Additionally, continuous evaluation and adjustment based on feedback are essential to ensure the effectiveness and sustainability of the proposed changes. Overall, the " Step wise method / Formulas" approach has the potential to transform traditional engineering education to better prepare graduates for global competition and contribute to national development.

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