ENGINEERING EDUCATION IN INDIA – SHORT & MEDIUM TERM PERSPECTIVES

BVR Mohan Reddy, Chairman & Members of AICTE Committee for Preparing Short & Medium-term Perspective Plan for Technical Education

Preface

The All India Council for Technical Education (AICTE) has been ably spearheading the planning, formulation, and dissemination of technical education across India. Over the years, it has undertaken several proactive steps for the growth of engineering education, maintenance of standards, and to keep the curricula current and relevant. While much has been accomplished, continuously changing expectations of the industry, society, and global stakeholder community owing to technology disruption, globalization and changing student preferences call for a review of the engineering education in India. In this endeavor, AICTE has constituted a Committee for Preparing Short & Medium Term Perspective Plan for Engineering Education in India.

The Committee studied the current state of engineering education in India. It has analyzed AICTE data on engineering capacity and enrolment trends across the country, several analyst and associations' reports on the technologies, jobs and skills, and engineering education trends of the future. When interpreted along with expert opinions, we found several gap areas and issues that require immediate attention to improve the enrolment in various disciplines, employability of graduating students, capabilities of faculty, and the quality of pedagogy. We present these as our recommendations in this report.

I sincerely acknowledge the proactive participation, insightful inputs, and outstanding suggestions provided by experts and fellow members on the Committee, Shobha Mishra Ghosh, Assistant Secretary General-FICCI, Dr Shalini Sharma, Senior Consultant and Head Higher Education, CII, Dr Sandhya Chintala, Vice-President-NASSCOM, Deepak Chabra, Senior Executive ASSOCHAM, Dr Jatinder Singh, Director-Ph.D.Chamber of Commerce & Industry, and Dr Raj Aggarwal, Director- Centre for Management Education, AIMA.

I like to acknowledge active participation of Dr MP Poonia, Vice Chairman, AICTE, Prof. Rajive Kumar, Advisor-I (P&AP Bureau), and NK Bhandari, Consultant (P&AP Bureau). They have been very helpful in providing raw data, insights into the workings of AICTE, and useful suggestions.

My gratitude to R Subramanyam, IAS, Secretary, MHRD, Dr SS Sandhu, IAS, Additional Secretary, MHRD and Prof Anil Sahasrabudhe, Chairman AICTE for the trust reposed in us and tasking us to develop this short- and medium-term perspective plan for engineering education in the country. I like to thank them for sparing their valuable time for reviewing some of the material.

Finally, I like to acknowledge and thank BhanuRekha Maturi from my office for her tireless efforts in putting this report together, providing insights into data with analytics, and making this report available in record-time.

BVR Mohan Reddy

Executive Summary

Technology and globalization have turned countries into knowledge–driven economies. They are radically accelerating the pace of change in the world and raising the long-term risks. Success in knowledge-driven and innovation-driven world order depends largely on the capabilities of the people, and higher education, especially engineering education, is the key to building those requisite capabilities.

India has done phenomenally well in creating large infrastructure across the country to disseminate engineering education to lakhs of aspirants in every State year after year. However, to be able to cater to the next-generation of engineering skill requirements, we need to facilitate quality and accredited technical education at scale.

In our efforts to support the reforms in engineering education, we have studied the current state of engineering education and present, in this report, our short and medium term perspectives and recommendations.

Recommendations:

1. Current (2017-18) capacity utilization in undergraduate and post-graduate level is as low as 49.8%. (Capacity Vs. Enrollment). Creating any further capacity is a big drain on investments since, at the very basic level, it involves the creation of physical infrastructure like buildings and lab infrastructure. We recommend that we do not create any new capacity starting from the academic year 2020. The creation of new capacity can be reviewed every two years after that.
2. While we take such a serious decision, we also recognize that there could be some applications in the pipeline for additional/new capacity applied in the last one or two years. These may be pending for want of some minor clearances. So, applications made in the current year and the past two years may be considered for starting institutions if the infrastructure is already in place.
3. We recommend that AICTE should take capacity utilization as a key consideration while granting additional capacities in different states.
4. Traditional engineering disciplines such as Mechanical, Electrical, Civil and Electronics engineering capacity utilization around 40% as opposed to Computer Science and Engineering, Aerospace Engineering, Mechatronics being in the high 60%. This is clear pointer that the demand lies in emerging technologies as opposed

to traditional engineering. We recommend that no additional seats are approved in traditional engineering areas, but institutions need to be encouraged to convert current capacity in traditional disciplines to emerging new technologies.

5. The poor employability of engineering graduates is reflecting poorly on the faculty – shortage and quality, and pedagogy. It may be very important to take immediate steps to improve the quality of our teachers.
    a. Competencies of the faculty need to be developed, especially in the areas of new age technologies and research through rigorous faculty development programs. Training of existing teachers at teachers training institutes, using quality improvement programs (QIP) and using IIT/NIT faculty and infrastructure are some of the immediate interventions we recommend.
    b. To bring about the desired change in the pedagogy in the immediate term, we recommend focused industry visits for faculty for hands-on exposure to the latest technologies. Industry associations could be leveraged in facilitating this.
    c. To improve pedagogy, we recommend engineering faculty to mandatorily have certification/diploma/degree in education.
6. Also, we may have to seek more technology interventions such as MOOCs to circumvent some of the constraints with faculty shortage and the quality of pedagogy. Students should be given more flexibility to use MOOCs in their core and optional curricula. Universities and autonomous institutions should be mandated to use MOOCs in the short term.
7. The low enrollment, lower placements, and low employability are causes for concern. Employment generation is very critical to a nation's economic development. While we are making certain recommendations on the role that academic institutes can play in improving the quality of education and indirectly contribute to the employment generation, all other stakeholders including government and industry should also start putting in place corrective measures to improve the employment generation.
8. As research becomes democratized, funds would need to be spent most optimally. Institutions need to build project management capabilities around research to ensure quick turnarounds, reduce cost and schedule overruns, and better collaborations across industry and academia.

9. Academic institutions have to continuously monitor the future skill requirements and make suitable changes to content and pedagogy so that the graduating students have the right capabilities for the job-in-demand. Hence, an institutional mechanism for periodic industry feedback on the technology upgradation and its impact on job roles needs to be put in place.
10. There is evidence to point out that the current industry-academia interaction requires improvement. We recommend the following interventions:
    a. Analytical tools should be used to understand the impact of various teaching methods and identify the best methods of executing coursework and apprenticeship – tightly integrate apprenticeship with pedagogy.
    b. Apprenticeship should be made mandatory on industry (in some ways it exists but needs rigorous implementation) and also progressively mandatory on educational institutions (starting with 25% moving to 100% in five years.
    c. Two industry representatives to be part of the advisory board of each institution.
    d. Deepening of industry-academia partnerships in applied research needs to be encouraged.
    e. Establish 20 National Knowledge Functional Hubs (NKFH) as a pilot in AICTE approved institutions to create an ecosystem of sustained industry-academia engagement.
    f. We recommend that AICTE takes the local industry ecosystem requirements (For instance, aerospace & IT engineering in Bangalore vicinity, automotive in Chennai and Pune) in to consideration while creating new capacities or increasing the existing capacities to deepen domain knowledge and to meet the industry requirements.
    g. Simultaneously, we recommend that AICTE balances this step with the national and global needs by introducing courses in new and disrupting technologies which are fungible across the country.
11. We have evidence to show that innovation, incubation and start-up eco-system is lacking in educational institutions. As has been rightly recognized by GOI, start-ups are a key driver for employment generation and wealth creation. Every education institution should be mandated for the following:
    a. Entrepreneurship should be a minor elective for undergraduates.

b. Tinkering labs similar to Atal Innovation Labs to be setup in every educational institution.

c. To promote start-ups, educational institutions need to setup incubation centers, mentoring clubs, and accelerator programs.

12. Proxy indicators such as venture capital investments and engineering R&D investments by large companies for forecasting future technology shows a clear trend towards software and internet industries, healthcare services, and medical devices and semiconductor industry. They also clearly indicate that **artificial intelligence (AI), internet of things (IoT) embedded SW, internet SW, mobility, analytics, and cloud** are growing at a rapid pace as compared to traditional technologies. The results of the NASSCOM - BCG study and FICCI-NASSCOM-EY study also concur with this analysis.

a. Across all engineering disciplines, we recommend, that courses in these emerging technologies are made part of the curricula and made mandatory for computer science, electrical, and electronics engineering.

b. Specifically, we recommend introducing undergraduate engineering programs exclusively focused in AI, IoT, Blockchain, Robotics, Quantum Computing, Data Sciences, Cyber Security, 3D Printing & Design, AR/VR (Indicative list).

c. Also, we recommend that we put greater focus on multi-disciplinary engineering courses, especially in computational biology, biotechnology, biomedical, mechatronics, space, aerospace, agriculture, and environmental engineering, by reducing the seats in conventional disciplines and converting some of the existing seats into these areas.

13. Research on future trends in education indicates student-centric learning needs to be given precedence.

a. We recommend students should be encouraged on design thinking and practical approaches to learning.

b. Students should also be made aware of real life socioeconomic problems for them to solve using technology learnings.

c. Technology should be used for individual learning paths for each student (Education 4.0).

d. MHRD/AICTE should make investments in innovation in education and incubate education start-ups.

e. Open book examinations should be introduced wherever applicable to move students to higher order cognitive skills.

14. Finally, developing a perspective plan for engineering education should be an ongoing exercise. In the backdrop of rapidly-changing technology environment, engineering education needs continuous monitoring. We recommend that one of the industry bodies or a smaller group of industry bodies with the help of consultants who have a focus on education be tasked with this periodic planning exercise once every two years.

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Engineering Education in India – Short & Medium Term Perspectives

I. INTRODUCTION

The 2005 book, ***The World is Flat: A Brief History of the Twenty-first Century*[1],** suggests that the world is in its third wave of globalization. The book recommends a perceptual shift required for countries, companies, and individuals to remain competitive in a global market in which historical and geographic divisions have become increasingly irrelevant. To this effect, globalization has made both developed and developing countries think about the effective and efficient strategies that can advance their economies and societies[2].

On the other hand, recent technological developments, especially the increasing computing powers and the declining costs of computing and storage along with commercial internet and communication technologies, have deconstructed several value chains and opened a new era of information/ knowledge economy. Given that technology and globalization are radically accelerating the pace of change and raising the long-term risks, it is clear that success in knowledge-based economies depends largely on the capabilities of the people.

This implies that higher education, in general, and technical education, in particular, is responsible for preparing the next generation of business leaders, government executives, and educators. Engineering education, in particular, plays a central role in knowledge-driven societies.

Turn to 2018, and the challenges associated with new and disruptive technologies of Industrie 4.0 are coinciding with the rapid emergence of ecological constraints, the advent of an increasingly multi-polar international order, and rising inequality. These integrated developments are bringing in a new era of globalization - Globalization 4.0.

[1] By Thomas L. Friedman

[2] https://bit.ly/2SBH0HJ

This has ushered in a new type of innovation-driven economy, that is disrupting and recombining countless industries and increasing the knowledge intensity of value creation. It is heightening competition within the domestic product, capital, and labor markets, as well as among countries adopting different trade and investment strategies.

It follows, then, that to effectively compete in knowledge-driven and innovation-driven economic order in the 21st century, India must invest in producing a large yet high-quality engineering graduates who are in tune with the future skill requirements. India has progressively built its engineering education capabilities over the decades and produces a large number of engineers every year. However, high quality and accredited engineering education and quality assurance mechanisms are the real imperatives for creating a world leader that India aspires to become in knowledge-based economies. Our engineering education must respond to local challenges as well as global opportunities. Engineering education must prepare our engineers for the multi-disciplinary nature of the problems of the modern organizations and societies.

To innovate and reform engineering education, it is important to understand in depth the current state of engineering education in India, the skills and competencies a future engineer must possess, and evolve action plans to bridge the gaps in short and medium terms. This report attempts to quantitatively and qualitatively analyze the current state of engineering education in the country under the ambit of AICTE and examines the employability levels of present-day engineering graduates. Delving in to the future, the report investigates and predicts, through proxy indicators, the technologies and industries that would play a significant role in the future. It also examines the future direction of engineering education itself and provides comprehensive recommendations to AICTE.

II. EXISTING CAPACITY UTILIZATION – ANALYSIS

Since its inception in 1945, AICTE has been planning and overseeing the coordinated development of technical education in India. To cater to the demand for affordable technical education in the country, AICTE expanded engineering education in India over the decades by adding capacity and creating an academic ambience for nurturing and supporting quality education across the country. Today, about 3,500 institutions are disseminating engineering education in India. However, it is observed that enrolment into various engineering courses has been on the decline in the country since 2012-13. AICTE has taken cognizance of the situation, and since 2016, it acted as a proactive regulator in reducing the number of engineering seats (capacity) in the country. This has helped in improving the seat utilization. Also, the pass percentages and placements for fresh graduates have steadily improved over the years.

i. Trend Analysis by Capacity & Intake:

Figure 1 gives the complete detail of AICTE engineering seats in the country in 2017-18 in undergraduate and post-graduate streams. A close look and analysis of this data highlight several important aspects. While the approved intake of engineering students across the country for the year was 16,62,470, the number of students who enrolled was 8,18,787, putting the enrolment at just about half the total approved capacity. This indicates the supply of engineering seats continues to exceed the demand for the same.

As per the data, the number of students who found placement at the end of the academic year was 3,45,215. This is about 42% of the total number of students who enrolled in engineering across the country. The data for the number of students passed is incomplete.

It is also observed that about 50.2% of all engineering seats are located in the five Southern States of India – Andhra Pradesh, Telangana, Tamil Nadu, Karnataka, and Kerala. Rest of the seats are fairly well-distributed across the country.

Our analysis of engineering seats across the states has also revealed that states with the lower number of seats have reported higher enrolment percentages while the states with larger capacity (>25,000) have reported lower % of enrolment in engineering, Karnataka being an exception. In Karnataka, a combination of early mover advantage and systematic capacity-building enabled higher capacity utilization.

Engineering seats data from 2017-2018

Together (UG+PG)	2017-2018					
State	Intake	Enrolment	Students passed	Students placed	Enrolment %	Place %
Tamil Nadu	3,02,259	1,58,715	17,089	82,618	53%	52%
Andhra Pradesh	1,94,611	1,01,077	6,310	36,122	52%	36%
Maharashtra	1,69,807	1,00,091	4,071	37,885	59%	38%
Telangana	1,56,804	75,855	3,277	33,510	48%	44%
Uttar Pradesh	1,33,863	47,069	3,563	24,145	35%	51%
Karnataka	1,13,794	73,452	1,100	25,597	65%	35%
Madhya Pradesh	99,095	44,233	1,188	18,627	45%	42%
Gujarat	75,585	36,284	10,031	10,075	48%	28%
Kerala	70,049	35,898	879	10,769	51%	30%
Rajasthan	57,329	18,038	179	8,592	31%	48%
Haryana	58,331	19,617	199	9,872	34%	50%
Odisha	47,563	18,282	243	11,872	38%	65%
Punjab	45,164	18,565	442	6,903	41%	37%
West Bengal	40,332	23,159	6,784	11,507	57%	50%
Chhattisgarh	23,314	8,921	25	3,211	38%	36%
Uttarakhand	12,661	4,318	60	2,328	34%	54%
Bihar	10,904	6,014	25	963	55%	16%
Delhi	10,731	8,529	1,016	3,616	79%	42%
Puducherry	9,397	3,605	87	1,977	38%	55%
Himachal Pradesh	7,350	1,968	38	897	27%	46%
Jharkhand	7,459	4,311	436	1,584	58%	37%
Assam	5,814	3,351		597	58%	18%
Jammu and Kashmir	3,483	2,555		596	73%	23%
Chandigarh	2,315	2,061		784	89%	38%
Goa	1,434	1,291		242	90%	19%
Sikkim	834	515		180	62%	35%
Meghalaya	660	126		60	19%	48%
Tripura	702	367	0	11	52%	3%
Nagaland	240	54			23%	0%
Arunachal Pradesh	306	223		56	73%	25%
Manipur	190	160		8	84%	5%
Andaman and Nicobar Islands	90	93		11	103%	12%
Grand Total	**16,62,470**	**8,18,787**	**57,042**	**3,45,215**	**50%**	**42%**

- Only UG & PG seats were considered
- 49% of the available seats in the country were filled
- 50.2% of all engineering seats are located in South India (AP,TS,TN,KA,KL)
- Rest of the seats are fairly well distributed across the country
- Data for Students passed for 2018 is incomplete

*Source: AICTE database

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Figure 1: Undergraduate and postgraduate engineering seats in 2017-18.

A further analysis of engineering data of the past five years throws up several insights requiring the attention of all stakeholders of engineering education. **Figure 2** and **Figure 3** show the trends.

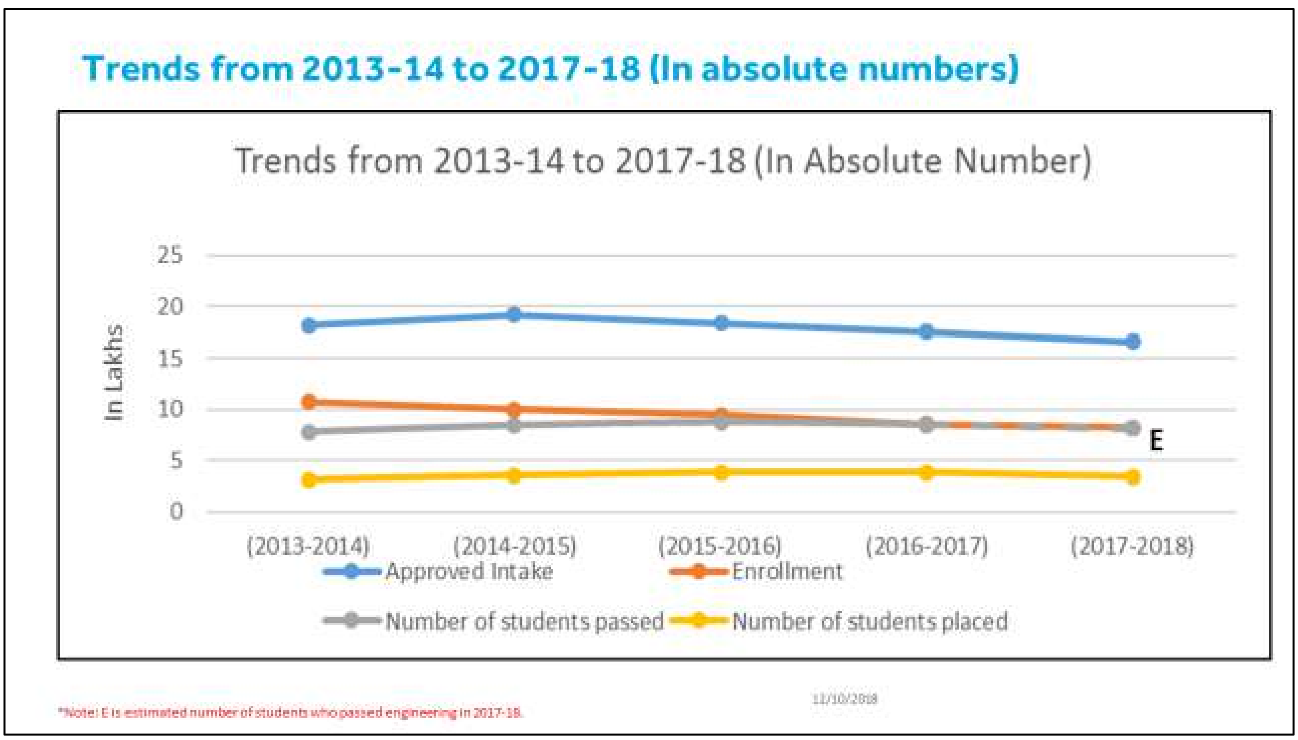


Figure 2: Engineering trends from 2013-14 to 2017-18 (in absolute numbers)

Figure 2 indicates that there has been a slight increase in the approved intake from 2013-14 (18,16,791) to 2014-15 (19,20,747). The same year, the enrolment dipped (10,71,395 in 2013-14 to 9,97,812 in 2014-15), widening the already existing gap between the supply and demand of engineering seats. But after that, the approved intake progressively fell, and in 2017-18, it stood at 16,62,470.

Despite the fall in the enrolment of students over the last five years, the number of students who found placement at the end of their courses remained more or less steady. However, when we turn to percentages (**Figure 3**), this indicates a progressive increase in the number of students who got placements – from 29% of students placed in 2013-14 to 42% in 2017-18, a remarkable achievement by AICTE.

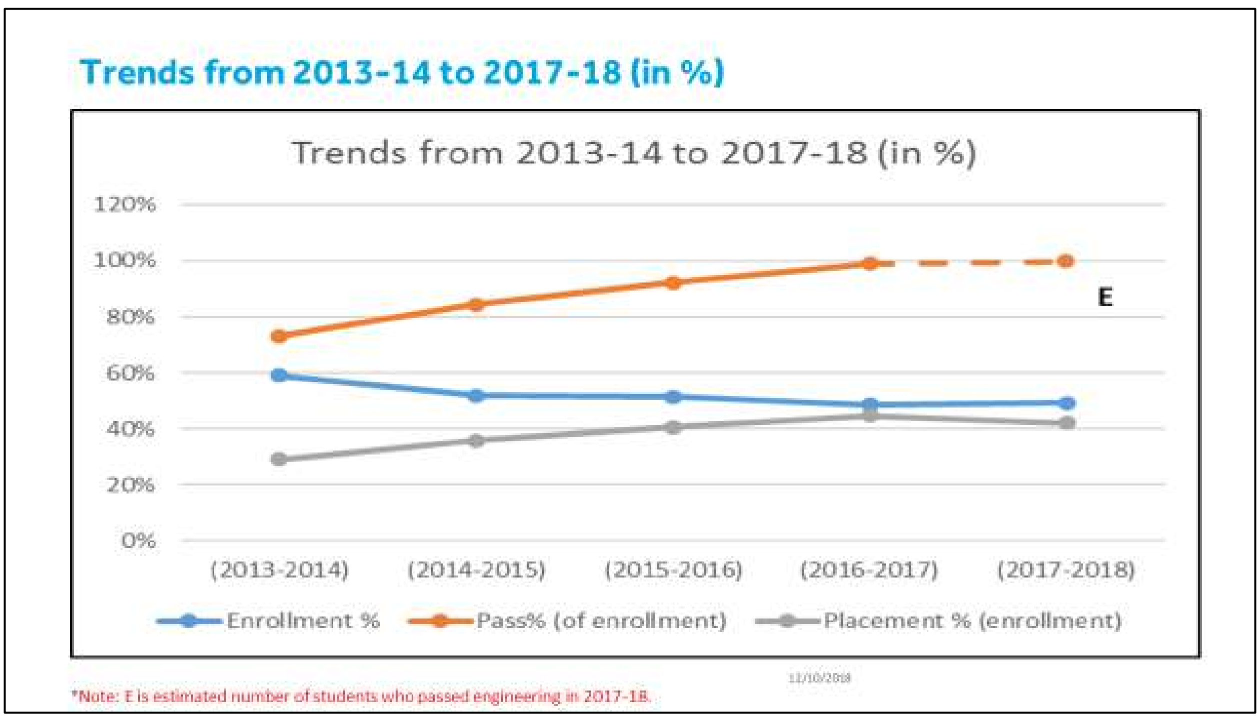


Figure 3: Engineering trends from 2013-14 to 2017-18 in percentages

Another trend that needs attention is the percentage of students enrolling in the engineering courses. While the enrolment was 59% of total capacity in 2013-14, this figure saw a progressive downward trend and stood at 49% in 2017-18. The percentage of students who have passed their courses has seen a progressive upward trend. In 2013-14, 73% of total students who enrolled completed their courses. This figure stood at 100% in 2016-17, remarkable growth in the students who have completed their courses.

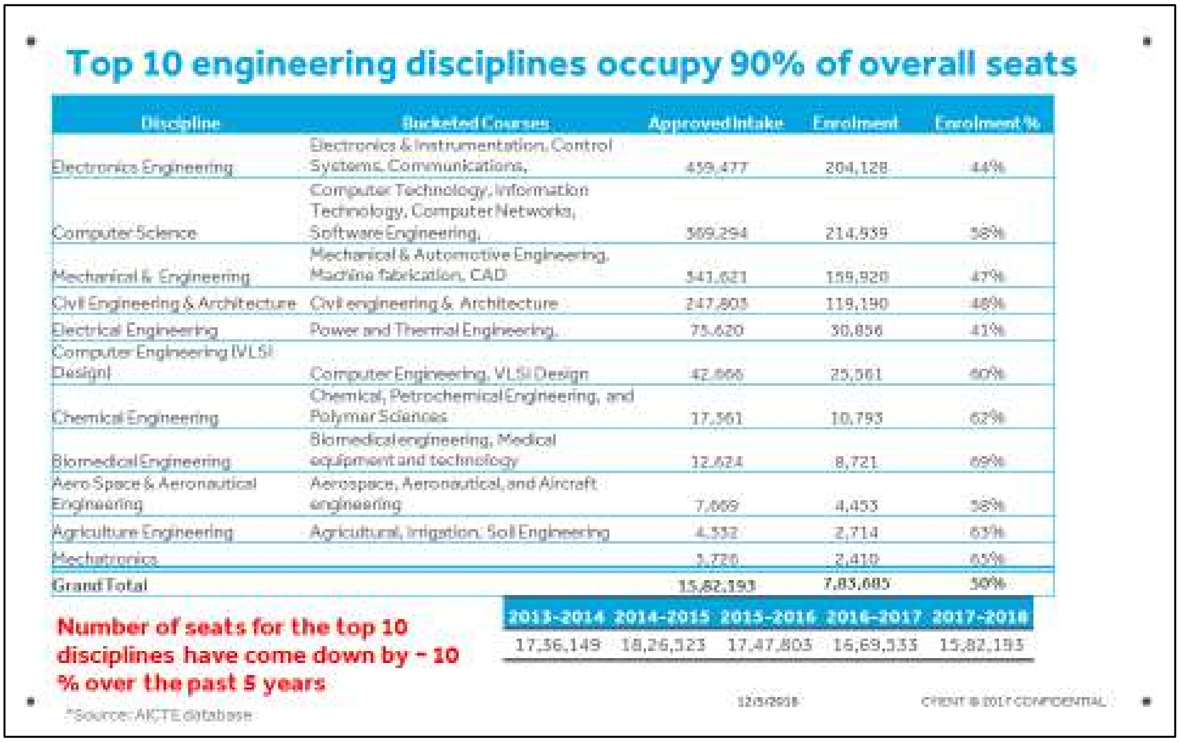
Recommendations to AICTE:

- Current (2017-18) capacity utilization in undergraduate and post-graduate level is as low as 49.8%. (Capacity Vs. Enrollment). Creating any further capacity is a big drain on investments since, at the very basic level, it involves the creation of physical infrastructure like buildings and lab infrastructure. We recommend that we do not create any new capacity starting from the academic year 2020. The creation of new capacity can be reviewed every two years after that.
- While we take such a serious decision, we also recognize that there could be some applications in the pipeline for additional/new capacity applied in the last one or two years. These may be pending for want of some minor clearances. So, applications made in the current year and the past two years may be considered for starting institutions if the infrastructure is already in place.
- We recommend that AICTE should take capacity utilization as a key consideration while granting additional capacities in different states.

ii. Trend Analysis by Discipline:

Engineering undergraduate and postgraduate courses are being offered under the purview of AICTE across the country in 437 different disciplines with a variety of nomenclature. To facilitate analysis, we have grouped these 437 sub-streams into 20 mainstreams.

For example, streams such as computer technology, information technology, computer networks, software engineering, information science and engineering, computer applications, computer software technology, GIS&GPS, cyber forensics, and information security have been grouped together under the discipline of "Computer Science."



Top 10 engineering disciplines occupy 90% of overall seats

Discipline	Bucketed Courses	Approved Intake	Enrolment	Enrolment %
Electronics Engineering	Electronics & Instrumentation, Control Systems, Communications,	459,477	204,128	44%
Computer Science	Computer Technology, Information Technology, Computer Networks, Software Engineering,	369,294	214,939	58%
Mechanical & Engineering	Mechanical & Automotive Engineering, Machine fabrication, CAD	341,621	159,920	47%
Civil Engineering & Architecture	Civil engineering & Architecture	247,803	119,190	48%
Electrical Engineering	Power and Thermal Engineering,	75,620	30,856	41%
Computer Engineering (VLSI Design)	Computer Engineering, VLSI Design	42,666	25,561	60%
Chemical Engineering	Chemical, Petrochemical Engineering, and Polymer Sciences	17,361	10,793	62%
Biomedical Engineering	Biomedical engineering, Medical equipment and technology	12,624	8,721	69%
Aero Space & Aeronautical Engineering	Aerospace, Aeronautical, and Aircraft engineering	7,669	4,453	58%
Agriculture Engineering	Agricultural, Irrigation, Soil Engineering	4,332	2,714	63%
Mechatronics		3,726	2,410	65%
Grand Total		15,82,193	7,83,685	50%

Number of seats for the top 10 disciplines have come down by ~ 10 % over the past 5 years

2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
17,36,149	18,26,323	17,47,803	16,69,333	15,82,193

*Source: AICTE database

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Figure 4: Top 10 engineering disciplines occupy 90% of overall seats

Further to this grouping, it is observed that the top 10 engineering disciplines constituted 15,82,193 approved in-take in 2017-18, which is 90% of the overall capacity in the country. Out of these 15.82 lakh seats, only 7,83,685 have been taken. This implies that just about 50% of the seats were enrolled even in the top 10 disciplines (**Figure 4**).

Also, the number of seats in these ten disciplines stood at 17,36,149 in 2013-14, while the same has fallen to 15,82,193 in 2017-18. This indicates a 10% drop in the approved intake of the top 10 engineering disciplines over the past five years.

We have further investigated the AICTE data of the past five years in terms of the engineering disciplines. **Figure 5, Figure 6,** and **Figure 7** highlight the trends in the approved intake and enrolment pattern in various disciplines.

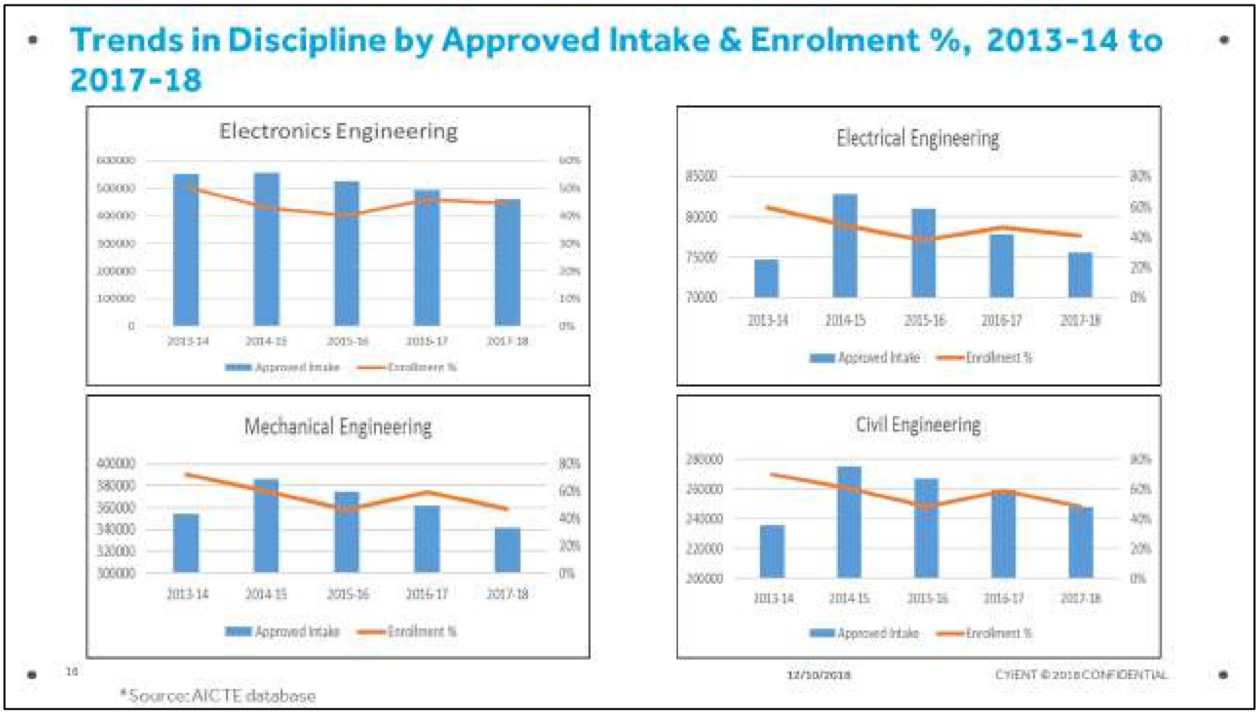


Figure 5: Trends by engineering discipline from 2013-14 to 2017-18

Take the trends in Civil Engineering discipline in **Figure 5**, for instance. Civil Engineering had an approved intake of about 2,35,803 seats in the country in 2013-14 and an enrolment percentage of more than 70%, which was much higher than the 59% average enrolment across disciplines for 2013-14. The approved intake increased to 2,75,136 in 2014-15. After that, the approved intake progressively fell, and in 2017-18, it was 2,47,803. The corresponding enrolment, however, had seen a consistent decline over the years and in 2017-18, it was 48%, indicating a decline in the interest and the demand for Civil Engineering discipline. We observe a contrasting trend in Computer Science engineering. The approved intake for Computer Science engineering has progressively declined from 4,39,151 in 2013-14 to 3,69,294 in 2017-18, but the enrolment has increased from 50% in 2013-14 to 58% in 2017-18, well above the average enrolment across disciplines during the year (**Figure 5**).

The above indicates that the demand for different disciplines of engineering change based on the technology trends reflecting on the industry and research needs. While it is very difficult to change capacities in the short term, we recommend that AICTE periodically (every two years) get an estimate of demand for types of engineering and also the requisite capacity.

Other traditional engineering disciplines such as Mechanical, Electrical, and Electronics engineering are following a similar trend as in Civil Engineering, and their capacity utilization is steadily falling and hovering around 40%, well below the country average across disciplines in 2017-18 (**Figure 5**).

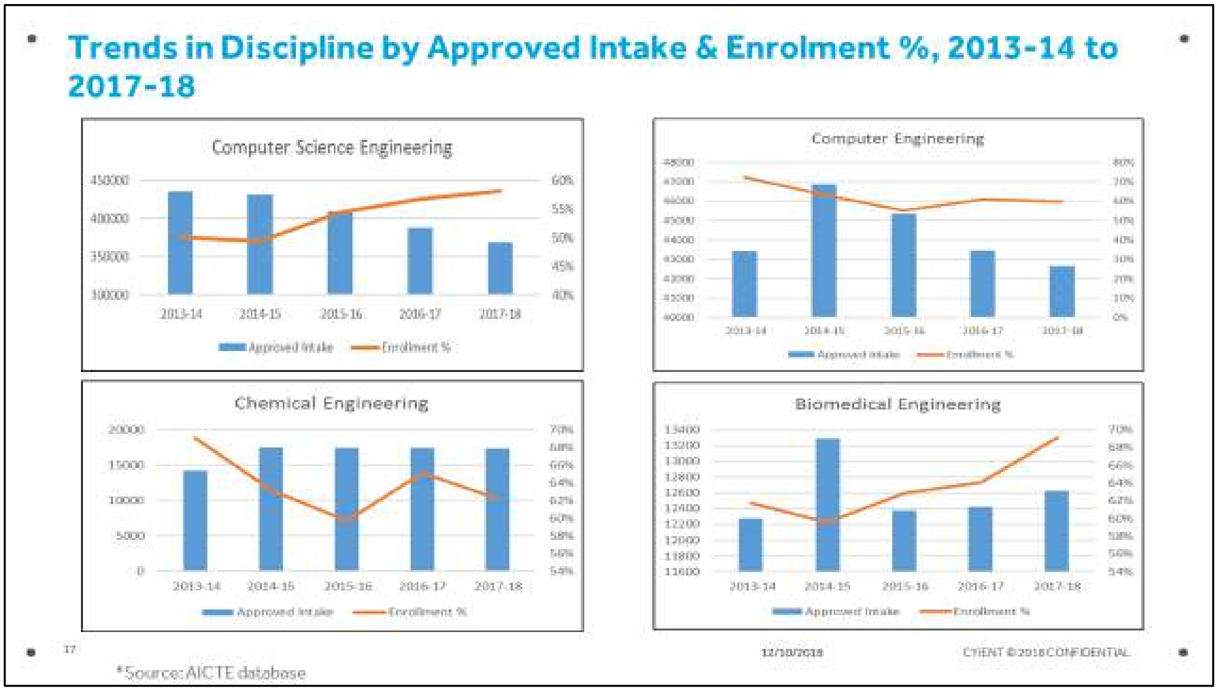


Figure 6: Trends by engineering discipline from 2013-14 to 2017-18

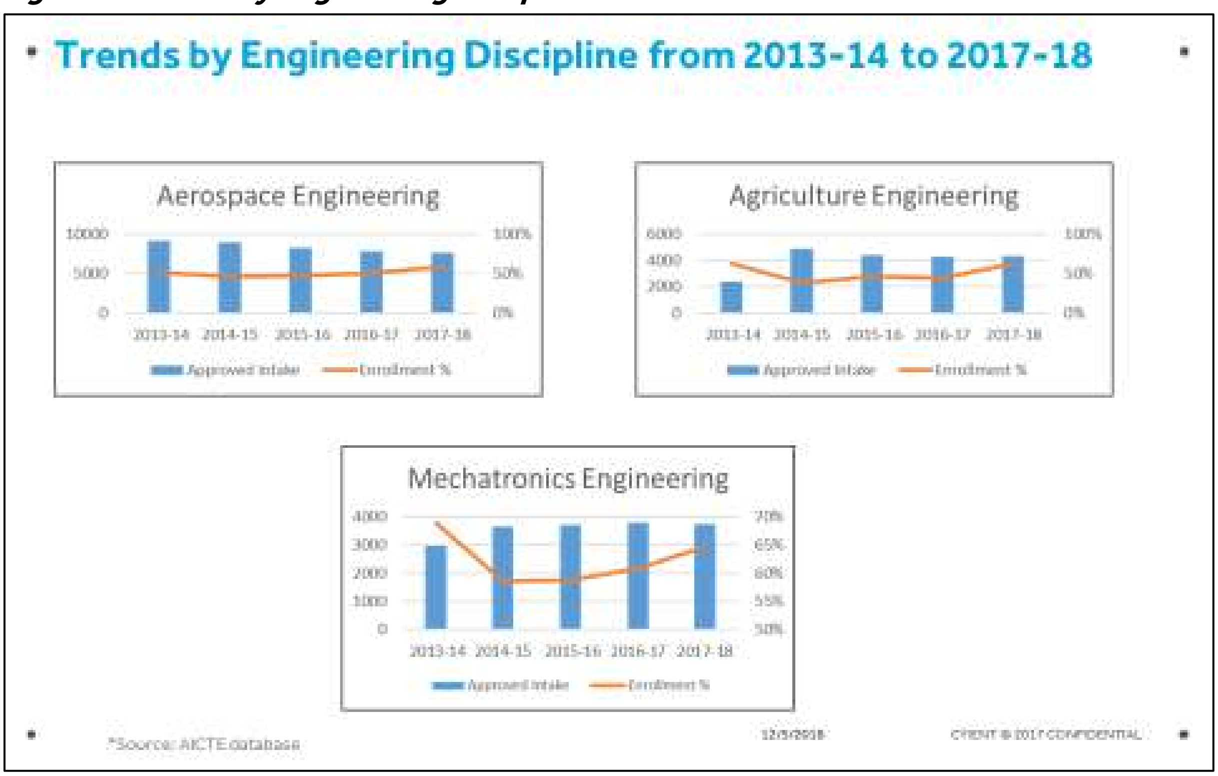


Figure 7: Trends by engineering discipline from 2013-14 to 2017-18

As opposed to this trend, the enrolment in Computer Science and Engineering, Aerospace Engineering, Mechatronics, and Biomedical Engineering is progressively increasing. For instance, Mechatronics reported 65% of enrolment (**Figure 7**) and Biomedical Engineering saw 69% enrolment (**Figure 6**) in 2017-18, much above the country average of 49%. This is a clear pointer that multi-disciplinary and emerging technologies are increasingly getting popular as opposed to traditional engineering disciplines.

Recommendations to AICTE:

- Traditional engineering disciplines such as Mechanical, Electrical, Civil and Electronics engineering capacity utilization around 40% as opposed to Computer Science and Engineering, Aerospace Engineering, Mechatronics being in the high 60%. This is clear pointer that the demand lies in emerging technologies as opposed to traditional engineering. We recommend that no additional seats are approved in traditional engineering areas, but institutions need to be encouraged to convert current capacity in traditional disciplines to emerging new technologies.

III. EMPLOYABILITY OF ENGINEERING GRADUATES

Engineering education has been transforming significantly in India in the past two decades, initially witnessing a meteoric rise in the supply of engineering graduates and recently a decline in the approved capacity. This period also saw a progressively widening gap between the industry requirements and the capability of engineering graduates, indicating an increasing gap between industry and academia and the siloed functioning of these two important stakeholders.

According to 2016 National Employability Report for Engineers by Aspiring Minds, which releases periodic reports based on an auditory mechanism for higher education, there is no significant improvement in the employability of engineering graduates in the preceding four years of the report.

The report based its findings on the survey of more than 150,000 engineering students (graduated in 2015) from 650+ engineering college across multiple Indian states. The analysis and findings are based on the results of these students on AMCAT: Aspiring Minds Computer Adaptive Test, an employability test (conducted in proctored and credible environment) that covers objective parameters such as English communication, quantitative aptitude, problem-solving skills, and knowledge of domain areas.

The report found that only 17.91% of engineers were employable for the software services sector, 3.67% for software products and 40.57% for a non-functional role such as BPO, a marginal increase over the previous edition of the report. This is despite the fact that the number of engineering seats has not increased in the 3-4 years. This indicates that our engineering education is focused on lower-order skills. **Figure 8 & Figure 9** further depict the trends in the employability of engineers in the country.

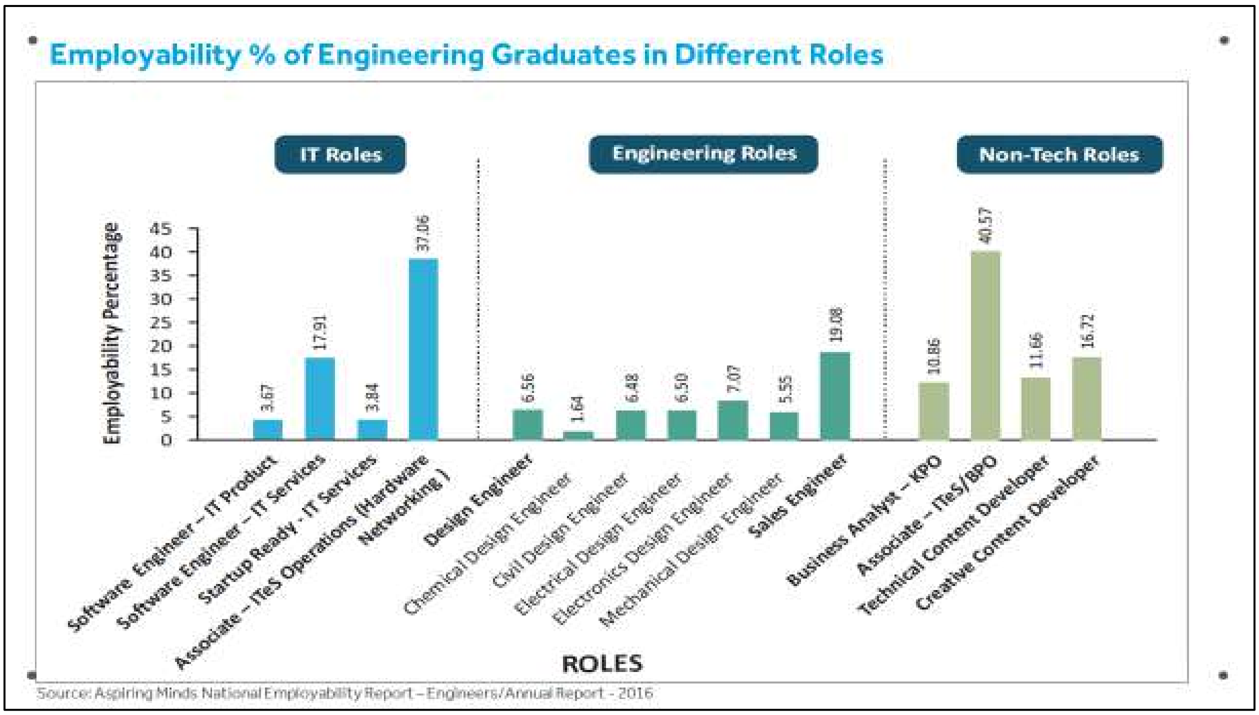
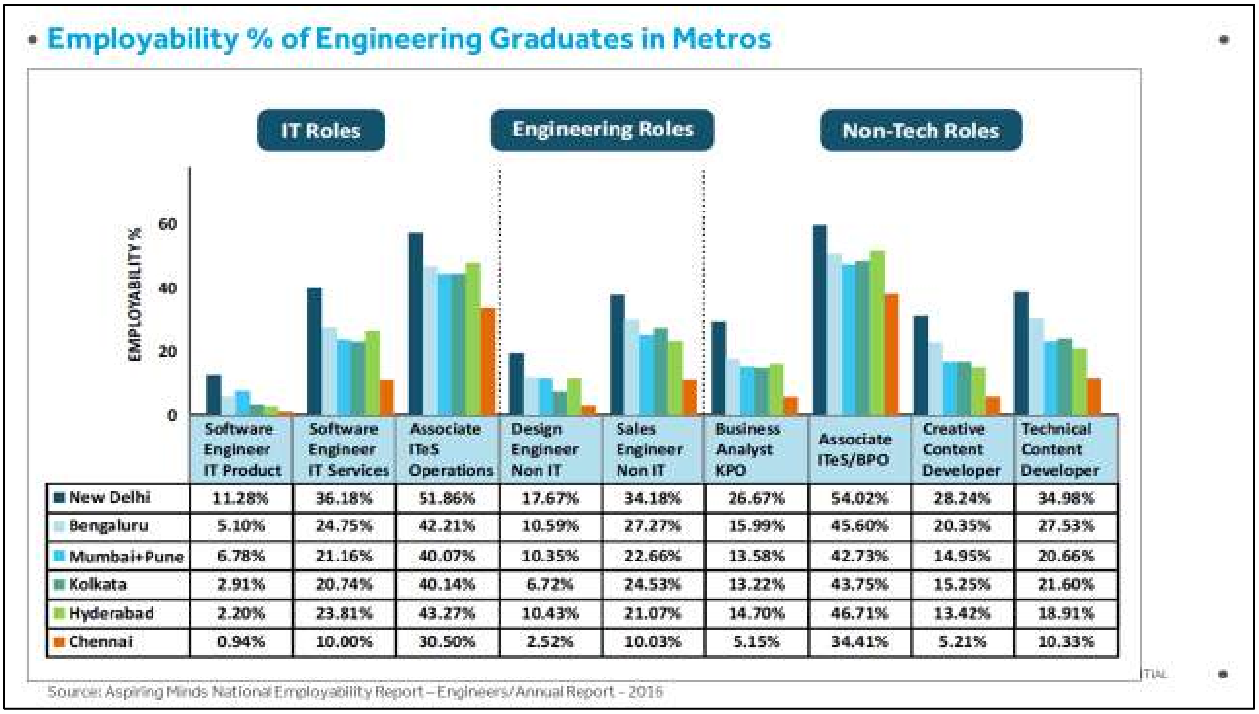


Figure 8: Employability % of engineering graduates in different roles
Source: National Employability Report-Engineers, Aspiring Minds, 2016

The report indicates that students from States such as Delhi, Kerala, Odisha, Bihar & Jharkhand have the highest employability (top 25 percentile). Sates Haryana, Karnataka, Punjab, and West Bengal form the next tier in employability (75-50 percentile). The third lower tier of states in terms of employability include Andhra Pradesh, Chattisgarh, Uttarakhand, and Uttar Pradesh (50-25 percentile).

At the bottom of the table in terms of employability are students from Gujarat, Himachal Pradesh, Maharashtra, Rajasthan and Tamil Nadu (0-25 percentile). Further, the report indicates that states with the highest number of engineering colleges show lowest % of employability (0.76 correlation between the log of a number of colleges and % of employability).



	Software Engineer IT Product	Software Engineer IT Services	Associate ITeS Operations	Design Engineer Non IT	Sales Engineer Non IT	Business Analyst KPO	Associate ITeS/BPO	Creative Content Developer	Technical Content Developer
New Delhi	11.28%	36.18%	51.86%	17.67%	34.18%	26.67%	54.02%	28.24%	34.98%
Bengaluru	5.10%	24.75%	42.21%	10.59%	27.27%	15.99%	45.60%	20.35%	27.53%
Mumbai+Pune	6.78%	21.16%	40.07%	10.35%	22.66%	13.58%	42.73%	14.95%	20.66%
Kolkata	2.91%	20.74%	40.14%	6.72%	24.53%	13.22%	43.75%	15.25%	21.60%
Hyderabad	2.20%	23.81%	43.27%	10.43%	21.07%	14.70%	46.71%	13.42%	18.91%
Chennai	0.94%	10.00%	30.50%	2.52%	10.03%	5.15%	34.41%	5.21%	10.33%

Figure 9: Employability of engineering graduates in metros
Source: National Employability Report-Engineers, Aspiring Minds, 2016

Simultaneously, it was observed that the southern cities, where there is a high proliferation of engineering colleges, show the lowest employability among the metros. Cities in Western India follow the southern cities with a high number of engineering colleges. Employability in Delhi is highest among the metros (**Figure 9**). This is attributed to the fewer number of engineering colleges in Delhi, despite the population of Delhi is more than any of the southern cities or Mumbai.

On similar lines, the Federation of Indian Chambers of Commerce and Industry (FICCI) and the World Bank (WB) had undertaken "Employer Satisfaction Survey" in 2009 (with 200 employers), and in 2014 (with 900 employers across 18 sectors) to map the satisfaction levels of employers with respect to the employability quotient of fresh engineering graduates. The 2014 study showed that the graduates had improved in their soft skills over the 2014 study. However, the technical skills remained as a matter of concern.[3]

Future Skills: Numerous studies around the world have tried to define employability skills and industry expectations. AICTE has listed requisite skillsets under the categories of "managerial skills, entrepreneurial skills, leadership skills, communication skills, and team-working skills" and mandated colleges and universities to impart these skills from the beginning. Some of the widely accepted and endorsed skills by colleges as suggested by agencies such as the National Board of Accreditation (NBA) include:

Attributes of Undergraduate Engineering Education			
1	Engineering knowledge	**7**	Environment & sustainability
2	Problem analysis	**8**	Ethics
3	Design and development solution	**9**	Individual and team work
4	Conduct investigation of complex problems	**10**	Communication
5	Modern tool usage	**11**	Project management & finance
6	The engineer and Society	**12**	Life-long learning

These skills can further be categorized into three core type of skills as below:

a. **Technical skills** - consisting of the core knowledge of the field, its application, programming skills and the ability to learn from basics
b. **Soft or professional skills** - consisting of a majority of STEM skilsl listed above including critical thinking and problem-solving skills
c. **Professional attitude** - including some of the STEM skills listed above plus a few additional skills such as ethics, integrity, and ownership.

According to Indo-Universal Collaboration for Engineering Education's (IUCEE) industry teaching fellows (ITF), a flagship body working to improve the quality and global relevance of engineering education and research in India, today's job market requires approximately 30% of technical skills and about 70% soft or professional skills to succeed[4]. Further, in the

[3] https://drive.google.com/file/d/1ngC1senpMARKSz1diMmMX6aIs6S7VmTC/view?usp=sharing
[4] http://iucee.org/iucee/wp-content/uploads/2017/10/ITF_Employability-White-Paper-Ver3.1.pdf

light of disruptive technologies, accelerated innovation, and complex business environment, the skills of the future are expected to change significantly.

A 2016 World Economic Forum report on the future of jobs detailed how skill requirement would morph over a decade[5]. The report says that on an average, by 2020, more than a third of the desired core skill sets of most occupations will be comprised of skills that are not yet considered crucial to the job as in 2016.

Figure 10 gives the change in demand for core work-related skills. As per this, more than one third (36%) of all jobs across all industries are expected to require complex problem-solving as one of their core skills, compared to less than 1 in 20 jobs (4%) that will have a core requirement for physical abilities such as physical strength or dexterity.

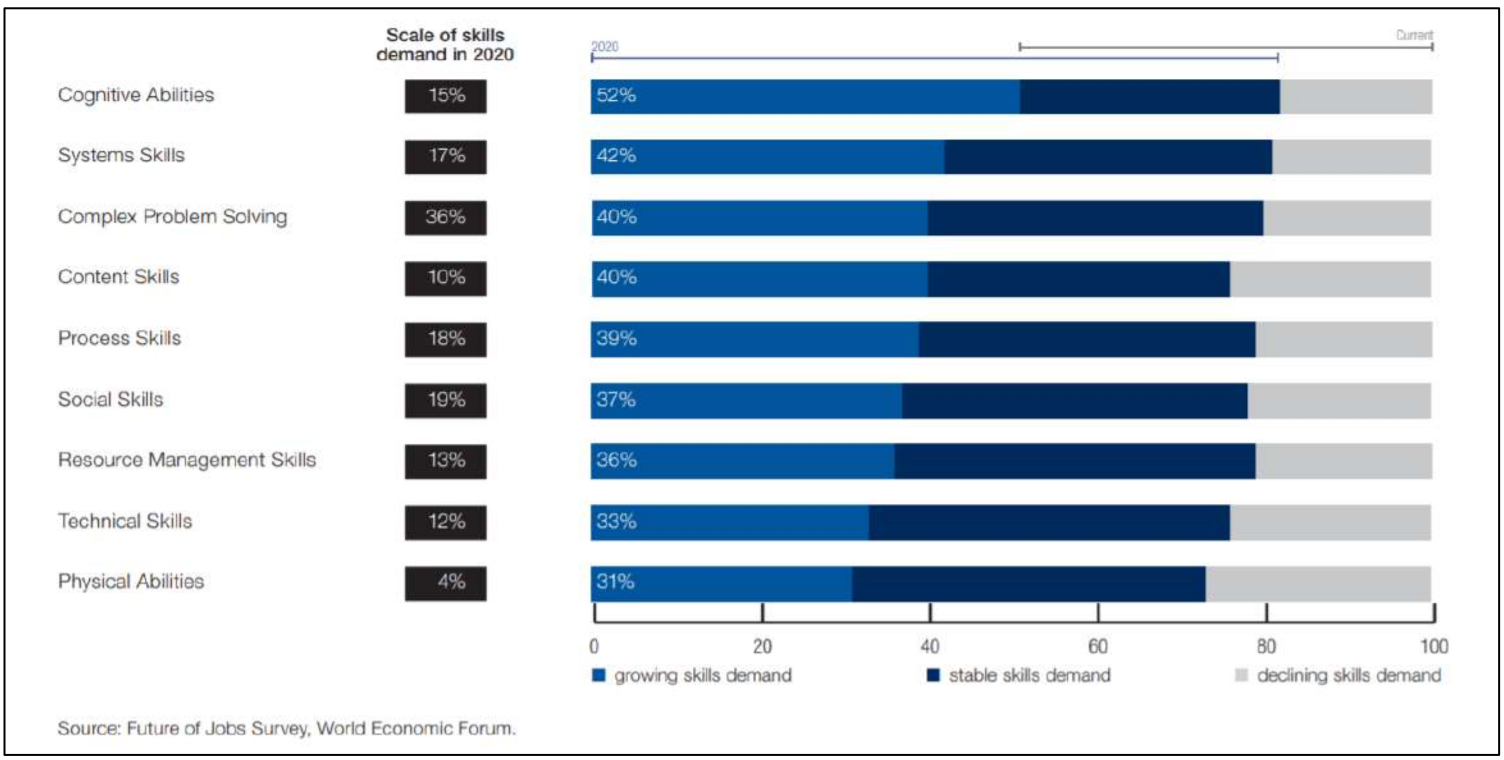


Figure 10: Change in demand for core work-related skills, 2015-2020, all industries
Source: Future of Jobs Report, World Economic Forum, 2016

[5] http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

The report opined that a wider range of occupations will require a higher degree of cognitive abilities – such as creativity, logical reasoning and problem solving sensitivity – as part of their cores skill set.

More than half (52%, the bright blue part of the bar in Figure 10) of all jobs expected to require these cognitive abilities as part of their core skill set in 2020 do not yet do so today, or only to a much smaller extent. In another 30% of jobs (the dark blue part of the bar in Figure 10), demand for these skills is currently already high and will remain so over the 2015-2020 period. Only 18% of jobs requiring high cognitive skills today are expected to do so less in the future (the grey part of the bar in Figure 10).

The report also points out that key technology trends are driven by AI, Big Data Analytics, IoT, and Cloud Computing, require engineers to gain not just the technical skills but higher order cognitive skills. Apart from cognitive ability, systems thinking, and complex problem solving would be few of the top skills that today's education system must address.

To study the Indian context, FICCI-NASSCOM-EY came up with an empirical report "Future of Jobs 2022", deep diving into two manufacturing (Automobile and Textiles) and three services sectors (Retail, BFSI, and IT & ITES). 100 CXOs were interviewed, and their reflections were collated, aggregated and analyzed.

The report estimates that on an average across these sectors, 9% of the workforce would be deployed in new jobs that do not exist today; 37% in jobs that have radically changed skill sets while 54% will fall under unchanged job categories.[6] **Figure 11** gives a snapshot of future jobs in the organized sector in 2022.

[6] http://ficci.in/spdocument/22951/FICCI-NASSCOM-EY-Report_Future-of-Jobs.pdf

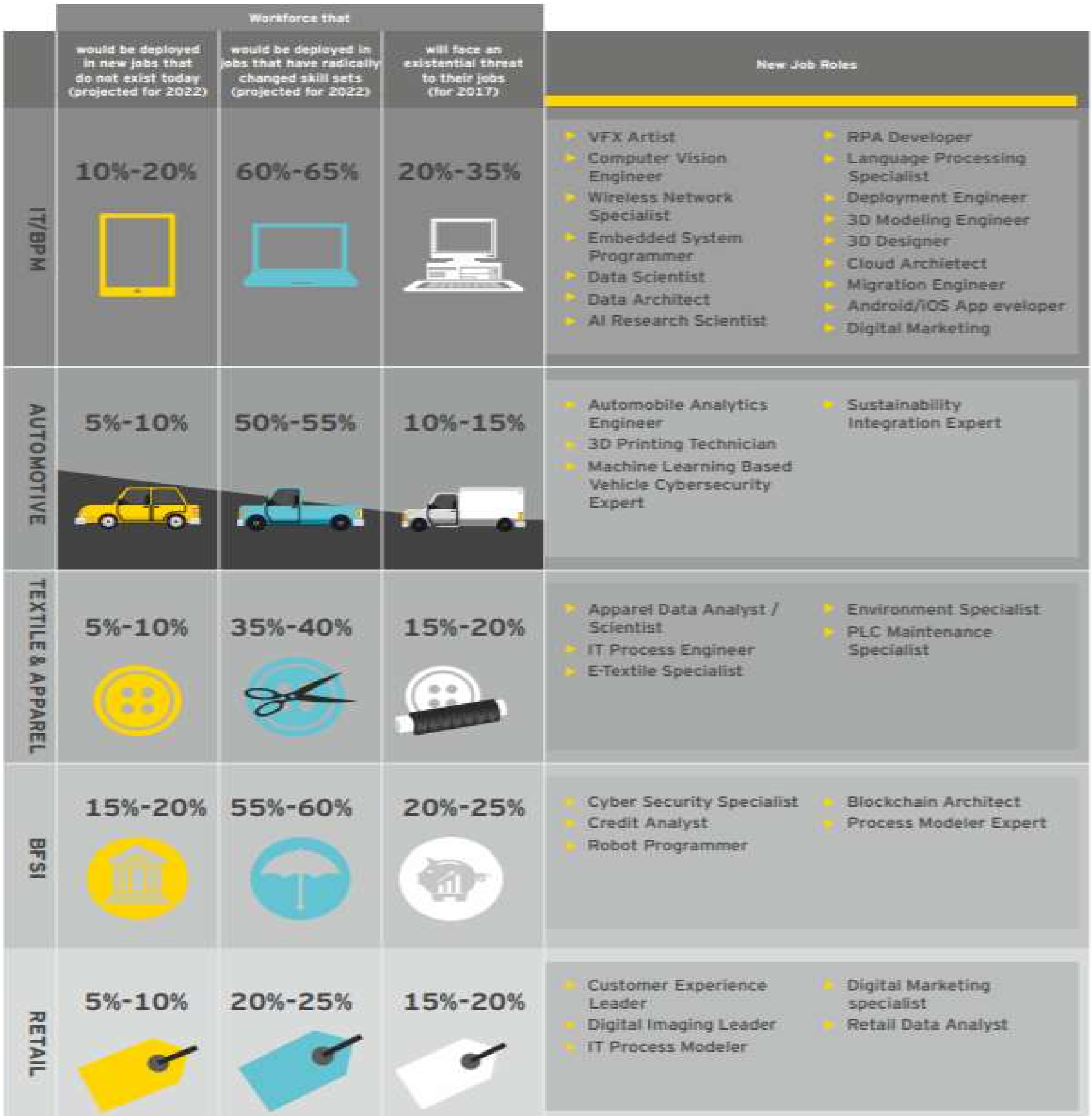


Figure 11: Snapshot of future jobs in the organized sector in 2022; Source: EY Analysis

Recommendations to AICTE:

- The poor employability of engineering graduates is reflecting poorly on the faculty – shortage and quality, and pedagogy. It may be very important to take immediate steps to improve the quality of our teachers.
    - Competencies of the faculty need to be developed, especially in the areas of new age technologies and research through rigorous faculty development programs. Training of existing teachers at teachers training institutes, using quality improvement programs (QIP) and using IIT/NIT faculty and infrastructure are some of the immediate interventions we recommend.

  - To bring about the desired change in the pedagogy in the immediate term, we recommend focused industry visits for faculty for hands-on exposure to the latest technologies. Industry associations could be leveraged in facilitating this.
  - To improve pedagogy, we recommend engineering faculty to mandatorily have certification/diploma/degree in education.
- Also, we may have to seek more technology interventions such as MOOCs to circumvent some of the constraints with faculty shortage and the quality of pedagogy. Students should be given more flexibility to use MOOCs in their core and optional curricula. Universities and autonomous institutions should be mandated to use MOOCs in the short term.
- The low enrollment, lower placements, and low employability are causes for concern. Employment generation is very critical to a nation's economic development. While we are making certain recommendations on the role that academic institutes can play in improving the quality of education and indirectly contribute to the employment generation, all other stakeholders including government and industry should also start putting in place corrective measures to improve the employment generation.
- As research becomes democratized, funds would need to be spent most optimally. Institutions need to build project management capabilities around research to ensure quick turnarounds, reduce cost and schedule overruns, and better collaborations across industry and academia.
- Academic institutions have to continuously monitor the future skill requirements and make suitable changes to the content and pedagogy so that the graduating students have the right capabilities for the job-in-demand. Hence, an institutional mechanism for periodic industry feedback on the technology upgradation and its impact on job roles, needs to be put in place.

IV. INDUSTRY-ACADEMIA PARTNERSHIPS

India's services-driven economy is growing rapidly, outpacing many countries in the world. As India Inc. strives to maintain its position in the global marketplace, businesses are proposing to double and treble their workforce. However, we have noted in the above section, the current engineering graduates lack the employability levels required by the industry. To bridge this demand-supply gap scenario, AICTE has been building partnerships with industry and has made several interventions over the years to improve the linkages.

In 2017, AICTE had made internships mandatory for all technical education students during summer vacations or regular semester and signed several MoUs both with government agencies and start-ups to support the institutes. It has been appealing to the industry to support its initiatives so that the graduating students learn to address the challenges of the future and enable the industry to get well-honed graduates.

The government has set up a target of 15 lakh apprentices for FY 2018-19 and 20 lakh for FY 2019-20, out of which 20 % should be fresh apprentices. However, only 2.30 lakh trade apprentices are undergoing apprenticeship training in 30,165 establishments across the country under the Apprentices Act, 1961. This is a miniscule number as compared to the total number of establishments in the country. Out of these, 36,000 apprentices are in Central Public Sector Undertakings/Central Government, and 1.94 lakh apprentices are in State Public Sector Undertaking/State Government Departments and Private Sector[7].

Further, the IT-ITES industry currently employs four million professionals and should be enrolling at least 100,000 apprentices per annum. However, so far the IT-ITEs industry has enrolled just about 23,158 apprentices.

One look at the 2018 AICTE-CII Survey of Industry-linked Technical Institutes reveals the current state of industry-academia linkages in the country. **Figure 12, Figure 13 & Figure 14** present more analysis.

The latest survey, which has gathered inputs from 9581 technical institutes under the purview of AICTE, has revealed that 78% of the total institutes have some linkages with industry, while 22% have no linkages at all.

[7] http://dget.nic.in/upload/5a5c874471a8aFinal%20Guidelines%20for%20NAPS7.9.pdf

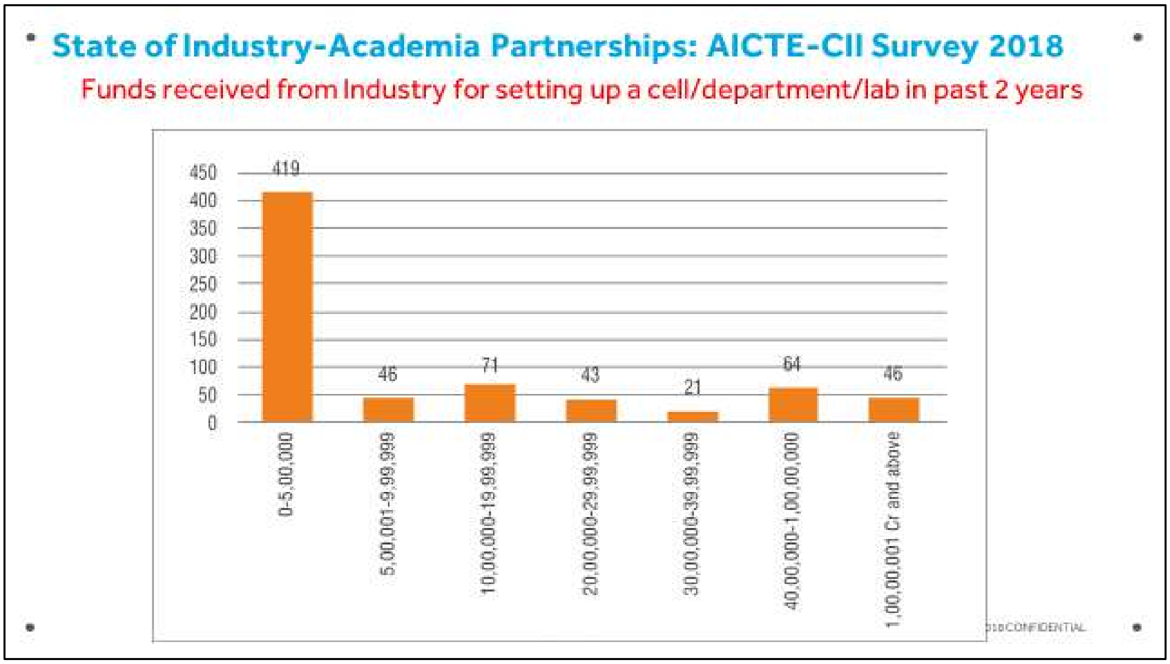


Figure 12: Funds received from industry for setting up a cell/department/lab in the past two years. Courtesy: AICTE-CII Survey 2018

Out of the 9581 institutes, 70% of the institutes are working with very few (<49) private sector organizations. In terms of funds received for setting up a department, cell or a laboratory, about 419 institutes received up to Rs 5 lakh from industry, while only 46 institutes received Rs 1 Cr and above (**Figure 12**).

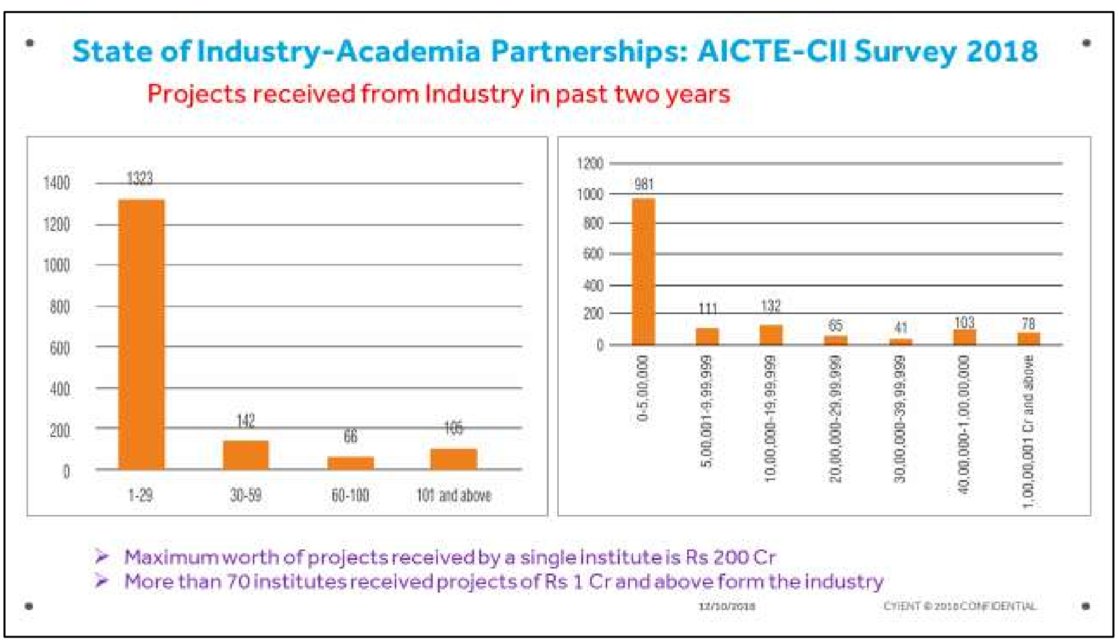


Figure 13: Projects received from industry in the past 2 years. Courtesy: AICTE-CII Survey 2018

Figure 13 analyses the number of projects received by the industry in the past two years. While a majority of institutes (1323) received very few projects of 1-29 in the last two years, about 105 institutes received more than a hundred projects. In terms of value, about 78 institutes received projects worth Rs 1 Cr and above from the industry, while the maximum worth of projects received by a single institute is Rs 200 Cr.

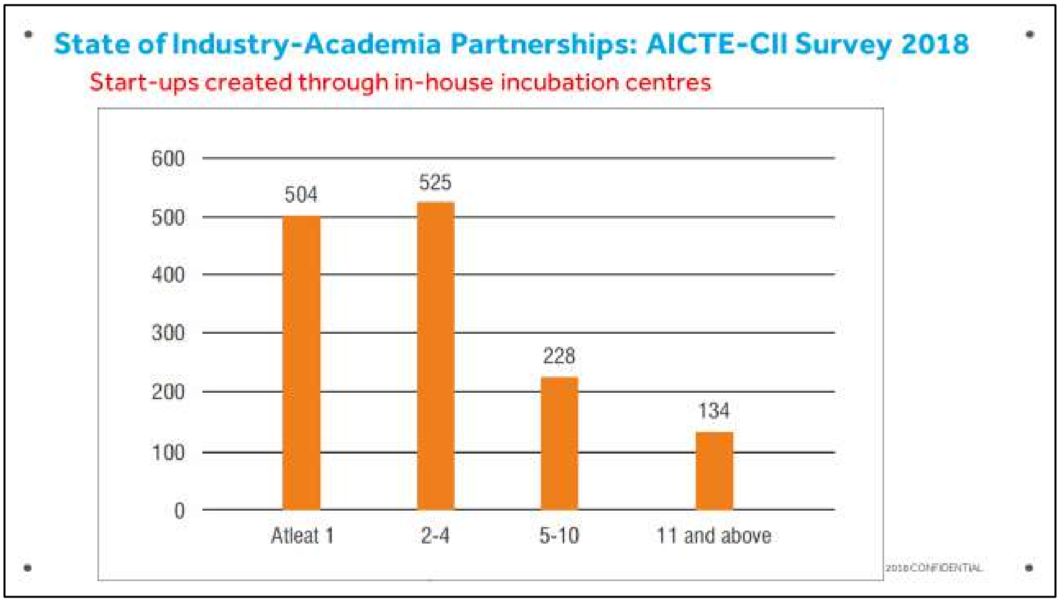


Figure 14: Start-ups created through in-house incubation centers. Courtesy: AICTE-CII Survey 2018

The survey further dwelt into understanding the depth of industry-academia linkages by analyzing the number of start-ups being incubated in the institutes (**Figure 14**). The survey reveals that 504 institutes have incubated at least one start-up and 525 institutes founded 2-4 start-ups in the past two years. Only 134 institutes have nurtured 11 and above start-ups within their in-house incubation centers.

It is evident from the survey that much more can be accomplished in deepening the linkages between industry and technical institutes in the country. It is important that all industry-academia partnerships go beyond placements. It is pertinent that industry participates in the boards of academic institutions and vice versa. This is to facilitate regular interactions between faculty and industry to provide inputs on curriculum, proactively explore potential joint research projects and create more start-ups that can complement and supplement the industry needs. It is only when more interaction happens that collaborations will flower and flourish and we can create an ecosystem to improve the job-readiness of fresh engineering graduates.

One of the ways to make this happen is to promote industry specific educational hubs/clusters across the country. Such hubs do exist in India (Mumbai and Bangalore for instance) at this point but are largely heterogeneous. The need of the hour is to have education hubs that are industry specific[8]. Creating clusters of industries and academic institutions at the same location would go a long way in helping academia collaborate with their respective industries. For instance, AICTE could have engineering colleges and technical training schools in an around Chennai and Pune where there is a large presence of the automobile industry. By the same logic, an IT cluster could be in Bangalore and Hyderabad. The major advantage of setting up these hubs is to create training facilities and internships for students and thus groom them for a solid career foundation.

Further, FICCI's study on industry-academia engagement in 2011 highlighted that while the elite institutions have best of the practices and engagement at all levels with industry, it is the tier II and tier II institutions that find it hard to engage with the industry due to lack of networking, resources, and capability. Similarly, while large corporations engage with top tier institutions, the bulk of SMEs are unable to engage with quality institutions either for consulting, research or student internship/apprenticeship. To tackle this paradox, FICCI had proposed the NKFH concept (a hub and spoke model) that was endorsed by the then Planning Commission (through the Narayan Murthy Committee Report on 'Corporate Engagement in Higher Education') in 2012 and by Ministry of HRD, Government of India the same year[9].

Recommendations to AICTE:

- There is evidence to point out that the current industry-academia interaction requires improvement. We recommend the following interventions:
  - Analytical tools should be used to understand the impact of various teaching methods and identify the best methods of executing coursework and apprenticeship – tightly integrate apprenticeship with pedagogy.
  - Apprenticeship should be made mandatory on industry (in some ways it exists but needs rigorous implementation) and also progressively mandatory on educational institutions (starting with 25% moving to 100% in five years.

[8] https://www.indiatoday.in/education-today/featurephilia/story/special-education-zones-for-academia-industry-collaboration-1097382-2017-11-30

[9] https://drive.google.com/drive/folders/19xjP6VE0-yLtKlqaRSKpXr3vbIDUO2W4?usp=sharing

  - Two industry representatives to be part of the advisory board of each institution.
  - Deepening of industry-academia partnerships in applied research needs to be encouraged.
  - Establish 20 National Knowledge Functional Hubs (NKFH) as a pilot in AICTE approved institutions to create an ecosystem of sustained industry-academia engagement.
  - We recommend that AICTE takes the local industry ecosystem requirements (For instance, aerospace & IT engineering in Bangalore vicinity, automotive in Chennai and Pune) in to consideration while creating new capacities or increasing the existing capacities to deepen domain knowledge and to meet the industry requirements.
  - Simultaneously, we recommend that AICTE balances this step with the national and global needs by introducing courses in new and disrupting technologies which are fungible across the country.
- We have evidence to show that innovation, incubation and start-up ecosystem is lacking in educational institutions. As has been rightly recognized by GOI, start-ups are a key driver for employment generation and wealth creation. Every education institution should be mandated for the following:
  - Entrepreneurship should be a minor elective for undergraduates.
  - Tinkering labs similar to Atal Innovation Labs to be setup in every educational institution.
  - To promote start-ups, educational institutions need to setup incubation centers, mentoring clubs, and accelerator programs.

V. FUTURE DEMAND FOR ENGINEERING DISCIPLINES

Technology is changing at a fast pace, requiring businesses to be more agile. A Gartner study points out that for 87% of business leaders, digitalization is a top priority. However, realizing the value of a great digital business vision requires building the right operational, technology and human capabilities.

To identify the disruptive digital technologies that are poised to grow tremendously in the coming decade, both nationally and globally, NASSCOM conducted a comprehensive study with Boston Consulting Group. The study identified **Artificial Intelligence, Internet of Things (IoT), Big Data Analytics, Robotic Process Automation (RPA), Cloud Computing, 3D Printing, Social and Mobile, Virtual Reality and Blockchain** as technologies that would create a huge wave of transformation across industries in the coming decade. Further, the study identified the future job roles and the corresponding skills required for these technologies. These are depicted in **Figure 15**.

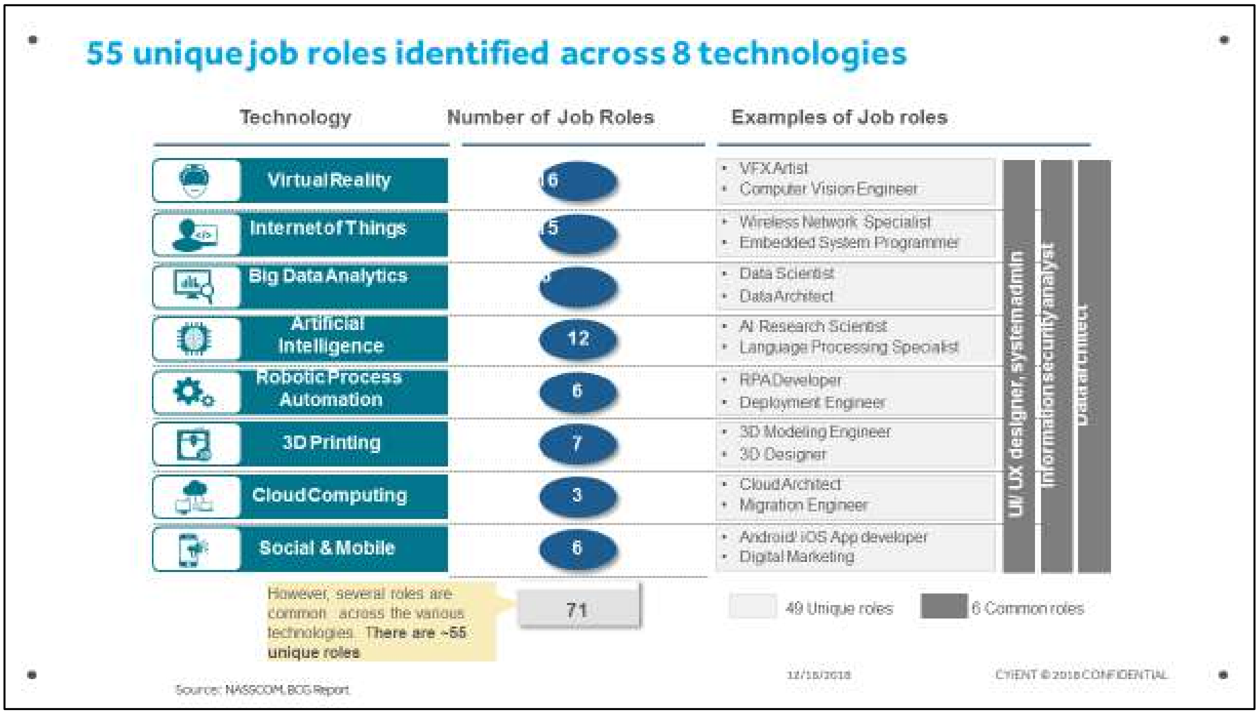


Figure 15: Eight new technologies and the corresponding 55 unique job roles. Courtesy: NASSCOM

The study found extensive evidence of accelerating demand for a variety of wholly new specialist roles related to understanding and leveraging these latest emerging technologies such as AI and machine learning specialists, big data specialists, process automation experts, information security analysts, user experience and human-machine interaction designers, robotics engineers, and blockchain specialists. For instance, artificial intelligence (AI) alone is poised to create 12 new job roles including solution architect, business analyst, data architect, data scientist, AI research scientist, language processing specialist, information security analyst, and DevOps engineer.

Further, it is important to note that these new technologies will find application in every other industry such as Agriculture, BFSI, Life Sciences, Pharmaceuticals, Healthcare, Retail, Automotive, Manufacturing, Energy, Genomics, and Transportation. For instance, evidence suggests that artificial intelligence, which is seeing unprecedented levels of investments across the world, can deliver real value in sectors such as healthcare. People will be able to take their skin lesion selfies and have their blemishes analysed for early detection of skin cancer using a smartphone app. AI is equally potent in the automotive sector, currently driving the driverless revolution (**Figure 16**). The power of sensors and cloud-based analytics is actively embraced for preventive heart care as much as it is used for environmental monitoring. Unmanned aerial vehicles (UAVs) and drones are being put to use in numerous ways by farmers in agriculture on one side and for surveillance by the armed forces on the other.

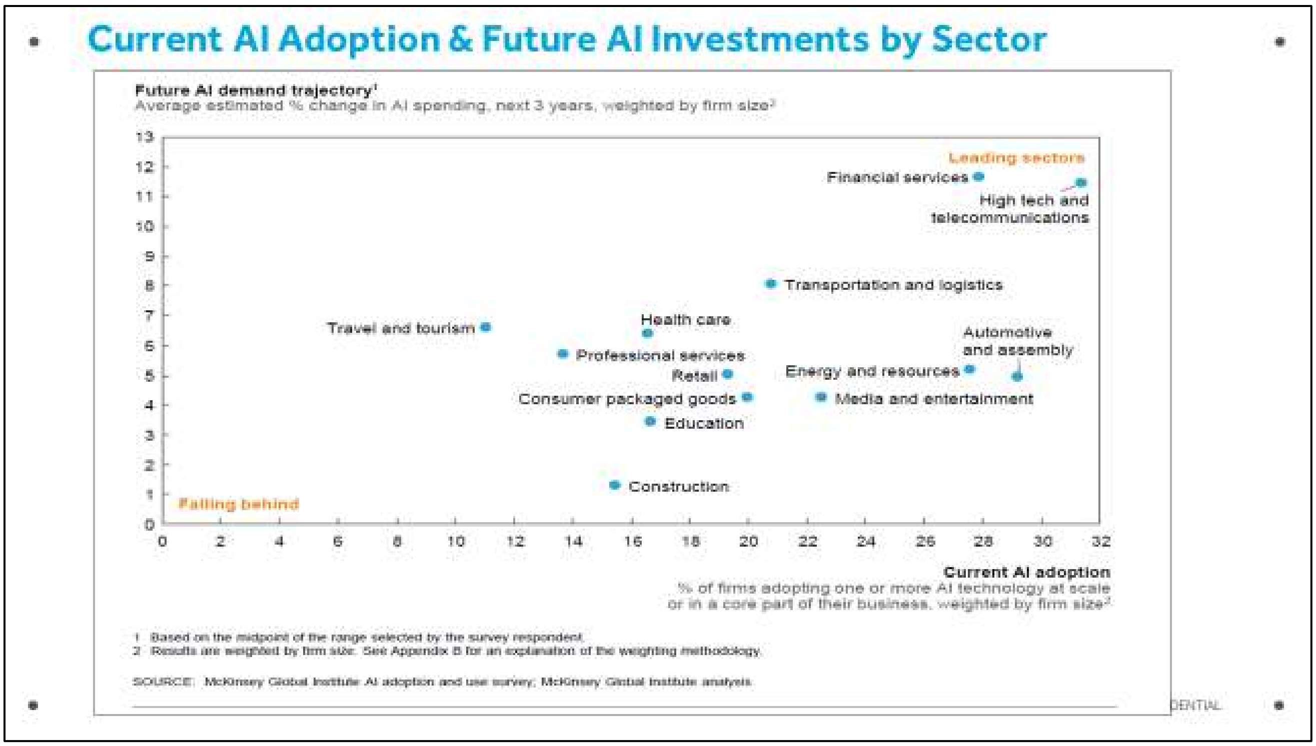


Figure 16: Current AI adoption & future AI investments by sector
Courtesy: AI The Next Digital Frontier? McKinsey Global Institute, 2017

This cross-sectoral application will have implications for the way we learn and work. Moreover, these technological advances are flanked by a range of socio-economic trends driving business opportunities in tandem with the spread of new technologies, such as national economic growth trajectories; expansion of education and the middle classes, in particular in developing economies; and the move towards a greener global economy. For this reason, it is important to bring greater focus on to multt-disciplinary courses, especially in computational bioinformatics, biotechnology, mechatronics, biomedical, etc. at the undergrad level.

From this analysis, it is imperative that ICT, specifically digital technologies, be made part of the curricula for every stream of engineering, especially for computer science, electrical and electronics engineering. Considering the vast scope of application of the digital technologies, it is pertinent that we introduce BTech in Artificial Intelligence, Internet of Things (IoT), Blockchain, Robotics, Quantum Engineering, Data Sciences, Cyber Security, 3D Printing & Design, and AR/VR. **Table 1** gives an indicative list of engineering disciplines that need to be introduced and the rationale for starting these courses. For instance, an undergrad program in AI could have core subjects such as matrix theory, pattern recognition and machine learning, IoT, robotics, data analytics, deep learning, drones, robot kinematics and dynamics, optimization methods, and machine diagnostics, along with essentials of computer science, mathematics, department and free electives.

S.No.	Discipline	Rationale
1.	Artificial Intelligence	Artificial intelligence, propelled by machine learning, computer vision, and internet of things, is fast evolving as a significant general purpose technology and is being pursued widely across all major sectors. This is one set of technologies which is witnessing unprecedented levels of investment across the world.
2.	Internet of Things	From smart homes to driverless cars to industrial, IoT is redefining the way we live. Like all digital technologies, the price/performance of IoT technologies is evolving at an exponential rate. The result is to make 'the invisible visible at scale.' We can now track our physical context with increasing granularity at ever-expanding levels and also dramatically improve their performance.
3.	Robotics	The demand for robots for personal services, and in many other industries, including healthcare, safety, and critical applications is growing rapidly. Robot suppression will become a key industry in the future.
4.	Cyber Security	Strict data protection directives and rising cyber terrorism is driving cybersecurity market to grow at a rapid pace. Healthcare, BFSI, IT and telecom industry verticals are expected to expand the utility of cybersecurity.
5.	Blockchain	Blockchain is another technology attracting lot of investments. Though the technology hasn't reached a mature stage, blockchain is touted as

		the second generation of internet and is finding application in BFSI, healthcare, property management, agriculture, governance, etc.
6.	Quantum Engineering	New discoveries of quantum impact to everything from nanotechnology to biotechnological processes are changing the outlook towards quantum computing. We already have a few degree-granting programs with names like 'engineering physics,' but this is a fairly broad label. Engineers in quantum engineering could work on chip fabrication, quantum computers, cryptography, nanotechnology, etc.
7.	Data Sciences /Big Data & Analytics	Big data is becoming a bigger part of the business, so does the need to understand and apply that data.
8.	3D Printing & Design	3D printing is fast becoming mainstream, with 3D printers being imagined for applications ranging from the manufacture of airplane wings to buildings, while the cost of 3D printing is falling substantially. With the rise of 3D printing as a means of manufacturing, the need for engineers who know how to design for 3D printing will be high.
9.	Augmented Reality/ Virtual Reality	Augmented Reality (AR) and Virtual Reality (VR) are becoming increasingly popular trends in the realm of consumer electronics, gaming, retail, industrial applications, healthcare, social communications, etc. It is predicted that augmented reality will have one billion users by 2020. The AR market is currently growing owing to its software growth, while the VR market is witnessing a high growth due to its hardware growth.

Table 1: Recommended engineering disciplines at undergrad level (indicative list, not an exhaustive list)

To further substantiate our understanding of the disciplines/topics, engineering streams and industry sectors that would shape the future of engineering education, we chose to study proxy indicators such as venture capital (VC) investments, and engineering R&D investments around the world and in India.

i. **Venture Capital Investments:** According to KPMG Venture Pulse Q4 2017 report, the global venture capital (VC) investment hit a decade-high of $ 155 billion in 2017. This is powered by the mega funding rounds in Asia and new capital investment rounds in North America and Europe. While the VC investment went up dramatically, the VC market saw a continuous decline in the volume of the deals, emphasizing the importance of the mega deals in the priority sectors.

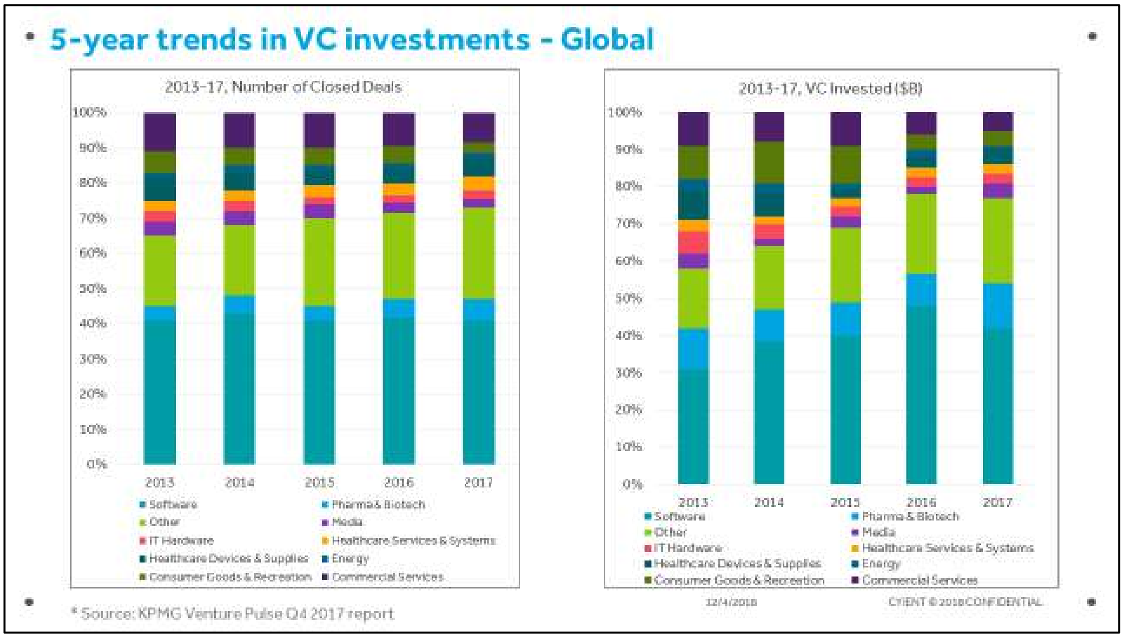


Figure 17: Five-year trends in venture capital investments from 2013-2017 – Global
Courtesy: KPMG Venture Pulse Q4 2017 Report

The key trends in VC investment in the last five years across the globe are as show in **Figure 17**. The report points out that **Software** continues to dominate with ~40% of overall investment across the world. **Pharmaceuticals**, **biotechnology**[10], and **healthcare**[11] saw a massive year-over-year increase in VC investments by 35% and are poised for additional growth.

VC investment in **artificial intelligence** doubled, attracting $12 billion of investment globally, compared to $6 billion in 2016. **Augmented Reality/Virtual reality** also saw significant interest from investors throughout 2017. The definition of AR/VR also continued to expand over the course of the year, with mobile AR and computer vision/machine learning (CV/ML) coming into their own as innovation opportunities.

Areas such as **healthtech, biotech,** and **autotech** are expected to gain more attention from investors over the next few quarters, while newer areas such as foodtech and agritech are well-positioned to become hot. In addition, it is expected that the VC market will see a major increase in investor focus on **cross-industry solutions** such as the applicability of AI

[10] Biotech: Biotechnology is any technological application that makes use of biological systems, living organisms and its components to create products and other technological systems (includes agriculture technology)

[11] Healthcare: Medical devices, Healthcare services (systems & management), lifestyle monitoring

across sectors, and the use of technology to increase the effectiveness and efficiency of less technology mature industries.

It is also observed that the Asian trends closely follow the global trends and the leading sectors are software, pharmaceuticals, and biotechnology in Asia as well.

An analysis of VC investments in India, which were relatively stronger in 2017, clearly indicates that **software** continues to be the leaders with ~40% of investments. **Software-as-a-service** and cross-industry applicable technologies such as **artificial intelligence, CRM** and **data analytics** have been hot areas of investor attention.

In terms of sectoral focus, **fintech** dominated investments in 2017, driven by the needs of demonetization and the implementation of new GST regime. **Healthcare** and **autotech** are emerging as strong sectors and are expected to receive significant investment in the next few quarters.

ii. **Engineering Research & Development (ER&D) investments:** To gain an insight into the potential future engineering disciplines, we have analyzed the evolving priorities for ER&D spenders. According to Zinnov Zones 2017 report on ER&D landscape, which analysed the top 500 R&D spenders across the world, **digital engineering** is driving R&D spending globally.

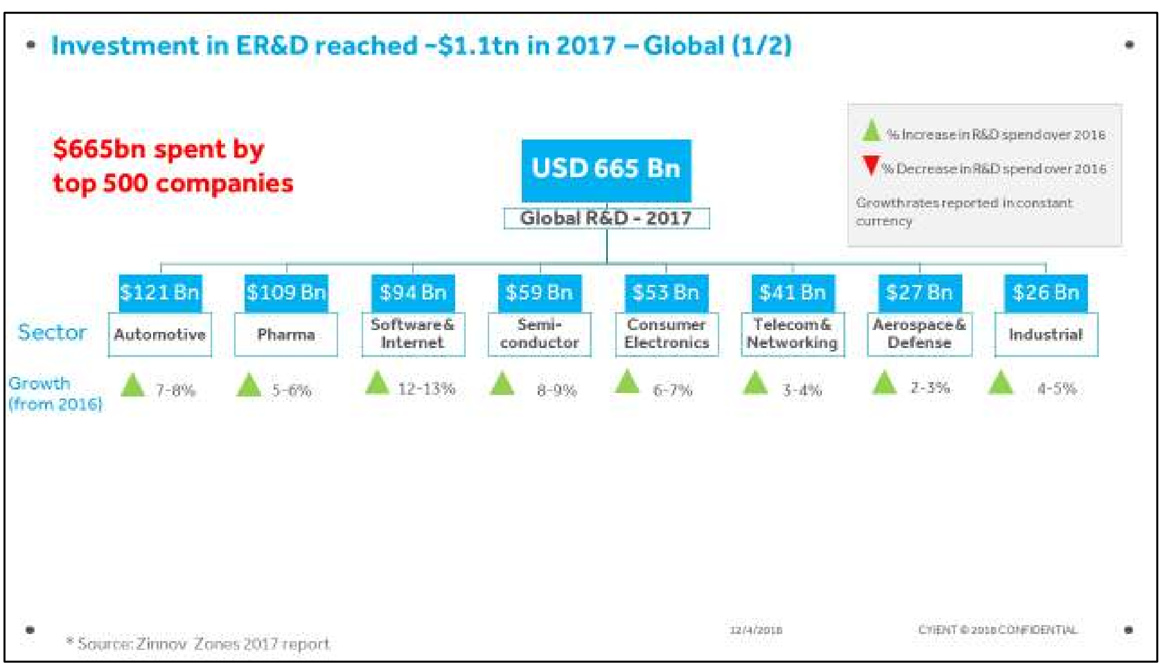


Figure 18: Investments in ER&D across the world (1/2); Courtesy: Zinnov Zones 2017 Report

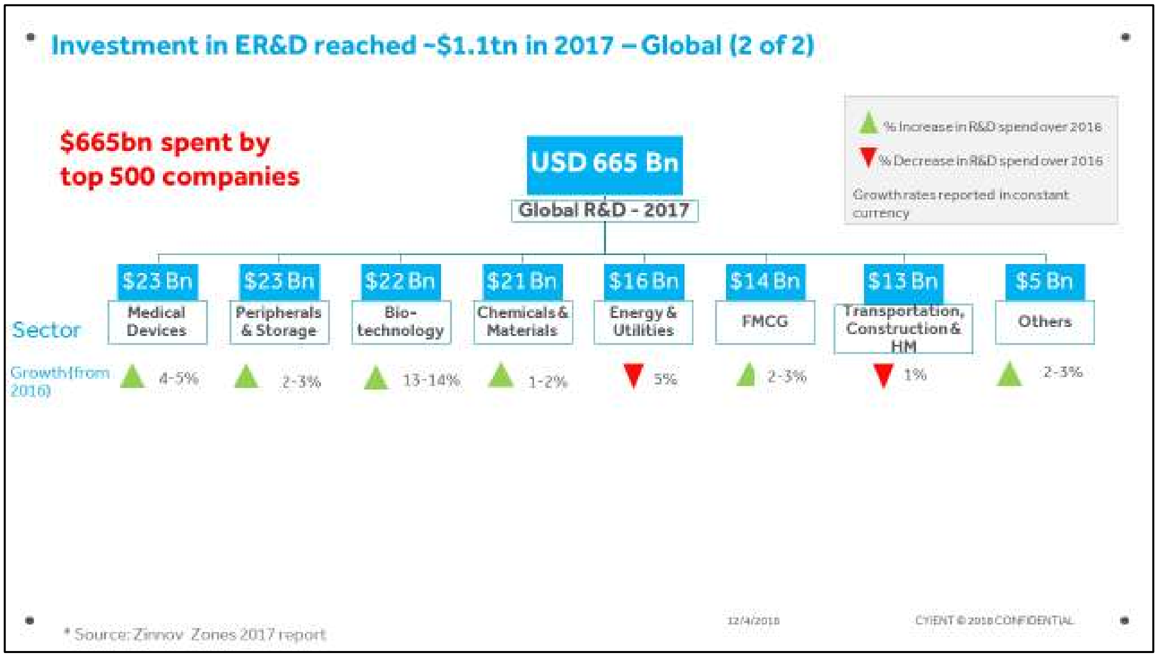


Figure 19: Investments in ER&D across the world (2/2); Courtesy: Zinnov Zones 2017 Report

The report pegs global corporate ER&D spend in 2017 at ~$ 1.1 bn with most R&D spent on verticals such as **software and internet, automotive, pharmaceuticals, semiconductors, consumer electronics, and telecommunications (Figure 18 & Figure 19)**. It is also observed that Pharma + Biotechnology + Medical Devices spend was $154bn in 2017 and is growing at ~9%, trailing only the Software & Internet sector.

Digital technologies[12] are playing a big role in traditional "mechanical engineering" sectors. For instance, R&D investment in the automotive sector is driven by electric and autonomous vehicles, advanced driver assistance systems (ADAS), Industry 4.0 and investments in aerospace & defense are driven by traditional mechanical engineering as well as digital technologies and data sciences.

Further analysis and projections in to the future (2022) reveal that the overall ER&D spend across the world would increase from $1097 billion in 2017 to $ 1,341 billion in 2022. However, the spend in **mechanical engineering** will mature or will stagnate (0-1% growth expected). The fastest growing investment segment is **software** with a strong focus on

[12] Digital Technologies includes artificial intelligence, IoT, AR/VR, digital twins, additive manufacturing, drone technology, robotic process automation, block-chain, data sciences.

digital skills. This sector is expected to increase R&D investments at 10-11% per annum to grow to $445 billion in 2022 from $269 billion in 2017.

Simultaneously, **embedded systems and applications** are expected to grow across all segments and investments in other engineering disciplines are expected to remain flat. **Figure 20** gives a quantitative understanding of ER&D investments in 2022. The analyses of VC investments and R&D spend significant emphasiss on **software and internet** with a special focus on **digital technologies** such as artificial intelligence, IoT, AR/VR, additive manufacturing, drone technology, robotic process automation, blockchain, and data sciences. These are in concurrence with the NASSCOM and BCG study cited earlier in this section.

Figure 20: Trend in ER&D spend across sectors (2017-2022)
Courtesy: Zinnov Zones 2017 Report

Recommendations to AICTE:

- Proxy indicators such as venture capital investments and engineering R&D investments by large companies for forecasting future technology shows a clear trend towards software and internet industries, healthcare services, and medical devices and semiconductor industry. They also clearly indicate that **artificial intelligence (AI), internet of things (IoT) embedded SW, internet SW, mobility,**

analytics, and cloud are growing at a rapid pace as compared to traditional technologies. The results of the NASSCOM - BCG study and FICCI-NASSCOM-EY study also concur with this analysis.

a. Across all engineering disciplines, we recommend, that courses in these emerging technologies are made part of the curricula and made mandatory for computer science, electrical, and electronics engineering.
b. Specifically, we recommend introducing undergraduate engineering programs exclusively focused in AI, IoT, Blockchain, Robotics, Quantum Computing, Data Sciences, Cyber Security, 3D Printing & Design, AR/VR (Indicative list).
c. Also, we recommend that we put greater focus on multi-disciplinary engineering courses, especially in computational biology, biotechnology, biomedical, mechatronics, space, aerospace, agriculture, and environmental engineering, by reducing the seats in conventional disciplines and converting some of the existing seats into these areas.

VI. FUTURE TRENDS IN ENGINEERING EDUCATION

Engineers have always played a key role in societal development, contributing to and enabling initiatives that drive economic progress, enhancing social and physical infrastructures, inspiring the changes that improve quality of life and bringing about a fundamental transformation in the society.

But today, as Industrie 4.0 gains ground, the world is witnessing the development of a few parallel trends including the rapid emergence of ecological constraints, the advent of an increasingly multi-polar international order, and rising inequality, ushering in a new era of globalization[13]. In this backdrop, the business environment is increasingly characterized by continuous change and growing complexity. The challenges for companies arise not only from the need for flexible technical solutions, but also from managing complex socio-technical systems, and contribute tangibly to the sustainable development of the economy and the environment.

This implies engineering researchers and graduates with the ability to understand complex technological processes in the context of social, environmental, economic, and global

[13] https://www.weforum.org/agenda/2018/11/globalization-4-what-does-it-mean-how-it-will-benefit-everyone/

concerns will play a critical role and will be increasingly sought after in the emerging industrial and business worlds.

In this context, it gets essential to understand the future direction of global engineering education and identify the defining trends to support positive educational change and build the next-gen engineering talent in the country. A recent MIT study[14] identified distinct anticipated shifts that will shape the leading engineering programs of the future.

i. **Shift in Center of Gravity:** The study anticipates that the focal point of top-class engineering programs will shift from the high-income countries of North America and Western Europe to the emerging economies of Asia and south America (**Figure 21**). This is due to the realization among emerging nations that to play a key role in knowledge-driven world order, it is imperative to invest strategically in engineering education and nurture the entrepreneurial ecosystem.

Figure 21: Global patterns of emerging leaders in engineering education; Source: The Global State of the Art in Engineering Education, March 2018, MIT

ii. **Shift in Curricula:** We have observed in the above section that future disciplines would be extremely different from the engineering streams of the present day. The emphasis is progressively shifting towards societally-relevant, multi-disciplinary

[14] https://bit.ly/2HtMuCx

streams while emphasizing on student's choices and experience outside the classroom.

iii. **Shift to Quality Education at Scale:** AICTE has enabled building an extraordinary scale of infrastructure catering to technical education in the country. The next task in front of the nation is to bring about a revolution in the quality of engineering education at scale under constrained budgets. There lie the challenge and their lies our ability to innovate and adopt the latest trends in curricula and pedagogy.

iv. **Shift to Student Centricity:** Another pertinent shift-in-the-waiting is moving towards student centricity. Our engineering education need to effectively cater to the needs of millennials and centennials who have low attention spans, and expect flexibility in learning. In the longer run, some of the leading engineering programs are moving towards delivering integrated student-centered learning at scale through a combination of off-campus and on-campus learning that is personalized, experiential, and flexible.

Recommendations to AICTE:

➢ Research on future trends in education indicates student-centric learning needs to be given precedence.

a. We recommend students should be encouraged on design thinking and practical approaches to learning.
b. Students should also be made aware of real life socioeconomic problems for them to solve using technology learnings.
c. Technology should be used for individual learning paths for each student (Education 4.0).
d. MHRD/AICTE should make investments in innovation in education and incubate education start-ups.
e. Open book examinations should be introduced wherever applicable to move students to higher order cognitive skills.

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