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Changing Paradigms of Engineering Education – An Indian Perspective

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Abstract

VUCA (Volatile, uncertain, complex and ambiguous) characterize the engineering education scenario. Engineers form the backbone of any country's economy. Around 25% of the world's engineers are in India but it lags behind in research and innovation. At the global level, engineering education is experiencing a paradigm shift from teacher-centric to student-centric teaching- learning process, content based education to outcome based education, knowledge seeking to knowledge sharing classrooms, teachers to facilitators, traditional engineering disciplines to interdisciplinary courses, chalk and board (lecture based) learning to technology driven learning and the list goes on. But in India, still conventional teaching – learning practices with little practical training is adopted in many institutions. This is shown by the fact the Indian institutions still struggle to make a position in world ranking with few exceptions. A country which pioneered in engineering, medicine, arts and music etc. in ancient era, suffers major setbacks in technical education.

Hence this study attempts to analyse the perception of stakeholders, viz. students, parents, academic faculty and industry, on engineering education and the future of engineering education. Focus group consultations with select group of respondents were carried out. The results were analysed which showed that the students perceive positively on engineering education but at the same time are apprehensive about the position of engineers in the society. Parents' perception towards engineering is solely on the job opportunities but the faculty members opined changes in the mindset of students and the impact of social media on general attitude. Industries expressed lack of employable engineers and lack of skills in new age technologies. Overall the respondents favoured the introduction of new and multidisciplinary courses to meet future demands.

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1. Introduction

Engineering, the term derived from Latin, means "cleverness" and Engineers (from ingeniare) are meant to contrive and devise. They are the backbone of the country's economy and are core of the overall development of people's quality of life. Origin of engineering education in India dates back to British rule majorly for infrastructural development. Post independence, Indian leaders acknowledged the significance of engineering education and established national, state/regional and divisional level engineering institutions. Till 1990, growth of institutions was steady but the scenario took an upturn with the advent of computer technology. Today, India produces around 1.5 million engineers from its 6000+ colleges every year. These educational institutions and engineering educators own the responsibility of producing competent and skilled engineers to cope with the changing requirements of the industry. Emerging contours of work in Industry 4.0 revolution is augmented by machines, algorithms and automation. This ever changing uncertain job markets' expectation of uncompromised supremacy in skill set of their employees pose a serious challenge to technical educational institutions. In future, traditional engineering courses may be replaced by new age technology courses such as, Artificial Intelligence, Full Stack Engineering, Robotics, Cloud Computing, Big Data Analytics etc.

At this juncture, it is appropriate to quote UR Rao Committee, which warned a glut of engineering graduates and such rapid expansion of technical education could not be sustained in the long run [7]. But to bring in sustainability in engineering education, educational institutions and the educators must deepen their pedagogical content by integrating their knowledge for effective teaching of STEM (Science, Technology, Engineering and Math) concepts. Engineering education has to balance the two ends of the spectrum (mushroom growth in engineering institutions and quality of education) with other environmental constraints such as regulations by apex organizations such as AICTE, NBA, Washington Accord, ABET, Seoul Accord (IT engineering) and stakeholders' demands. Mere engineering degree will not be enough for the job markets. Students with employable skill sets are the need of the hour for the job markets.

This study attempted to identify substantial and emerging strengths of Indian engineering education in addressing industry-specific skills shortages, to enumerate the means of addressing the challenges and robustness of the engineering education system with respect to its ability to graduate engineers for the future from stakeholders' perspective. Focus groups comprising of engineering students, parents, engineering educators, industry representatives and academic heads of institutions are formed to analyse these issues and challenges. The focus group consultations revealed the changing trends in recruitment processes with advent of new age technologies, capricious students' mindset, demand to augment classroom education and immediate focus on upskilling of engineering teachers.

2. Review of Literature

Higher Education in India dates back to ancient period and British rule made a significant impact on Indian education system. In the ancient era India had been a hub for education in linguistic studies, arts and music, medicine, astronomy, martial arts etc and it attracted many foreigners to come to India for studies. Leading universities such as Nalanda, Taxshila, Valabhi, Vikrsmshila etc. [16] had been acclaimed to be top universities. Since then, the education system has undergone many significant changes. For example, British rule has made a profound change in the system by introducing English language teaching and established universities.

Interestingly, India is top ranked in producing around 1.5 million engineers graduate per year, that is 25% of the

world's engineers and science graduates [15] but it lacks in research and innovation [11] . In spite of this fact, Indian education institutions do not find top places in the world ranking [1]. This may be because of the emphasis on imparting theoretical knowledge with abysmal practical aspects and extensive practice of memory based assessments. This in turn has resulted in major challenges viz.

- Declining enrollments for engineering programs and in higher degrees by research
- Lack of qualified faculty members
- Lack of quality checks in academic appointments for technical teaching
- Lack of research facilities
- Inadequate infrastructure
- Inadequate and highly variable connections between the engineering institutions and industry
- Lack of employability skills for job market among the graduates
- Job markets' expectation of uncompromised supremacy in skill set of their employees and
- High societal perception on Engineering as a profession.

Technical education in India includes degree and diploma programmes in engineering, technology, management, architecture, town planning and the like. These sectors demand well qualified professional and need a closer collaboration between industry and institutions to drive innovation and research. The core of quality engineering education is the teaching- learning process, and is expected to combine efforts of both teachers and students to foster individual creativity and knowledge application [9]. The major challenge in transforming the teaching learning process would be the shortage of qualified faculty, poor quality of teaching [14], outdated methods of transaction, rigid curricula and pedagogies [13].

Curriculum for higher education should be developed to encompass the objectives of curriculum, subject matter, mode of transaction and assessments. Traditional practices of lecture and demo methods were highly teacher – centric approach, which should evolve to student-centric approach to meet the current demands [12]. The learning experience of the students should be enhanced through methods such as **experiential learning, participative learning, project based learning, industrial visits, guest lectures and problem solving methodologies.**

Conventional rule-based jobs, will be disrupted by advances in technology, such as Artificial Intelligence (AI), Machine Learning And Robotics, in line with what is happening in the West [6]. It is predicted that future jobs across various sectors, be it manufacturing , finance, banking, education, teaching, computer science or software will be automated [6]. At the same time, Cognizant [5] reports that, as technology develops to address societal needs, it simultaneously causes new problems which need human attention. Though, future jobs would be automated but at the same time, human ingenuity can never be replaced by the machines. Hence, students with the right skill set with specialist knowledge will be in demand for future jobs.

National Employability Report Engineers, 2019 [3] survey revealed that "*employability statistics have not changed over a decade*", i.e., 80% of the Indian engineers are not employable in any job in the current knowledge economy. The study further reported that only 4.5% have the required coding skills, a meager 2.5% is with Artificial intelligence and only 2.8% have any knowledge about wireless technologies. The report also pointed out that internships, project based learning are followed by only 40% of the students. The Gross Enrolment Ratio (GER) in Higher Education in India is at 25.8% [2] which is well below the global average. This is because of the unavailability of public universities, high fee structure in private organizations, lack of interdisciplinary learning, lack of industry participation in course development [8]. Mushroom growth of low quality institutions and absence of innovative teaching learning pedagogies also play a crucial role in the less GER of India.

The extant studies have revealed lacunae in higher education sector in India, encompassing the status of technical education, teaching-learning processes, employability skills and changing job markets. This study aims to analyse

the perceptions of engineering students, parents, industries and faculty members on the engineering education.

3. Research Methodology

Focus group consultation method was adopted as the research work needs an in-depth analysis of the perceptions of the stakeholders.

Focus group	Sampling method	Sample
Students	Systematic random sampling	Hostel : 2 Day scholars : 2 Girls : 2 Boys : 2 From each branch of study
Faculty members	Engineering faculty members with >15 years of teaching experience	2 members from each of the engineering disciplines (Civil Engineering, Computer Science and Engineering, Electrical and Electronics Engineering, Electronics and Communication Engineering, Electronics and Instrumentation Engineering, Mechanical Engineering and Information Technology)
Parents	Simple random (convenient) sampling	Parents who consented for the survey
Industry	Simple random (convenient) sampling	Placement coordinators / Industry reports

Limitations:

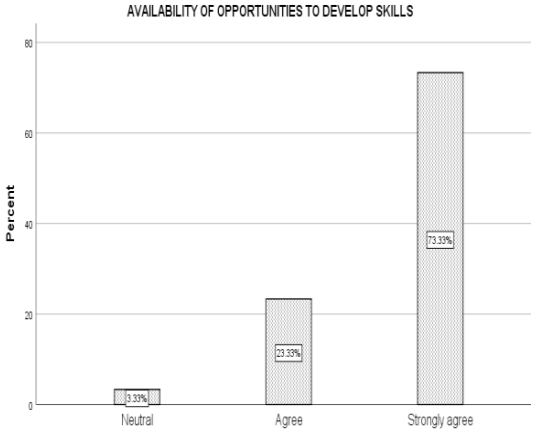
- Industry representations are less. Secondary data was used.
- The survey was taken from representative samples. The responses are purely on the perceptions of the respondents.

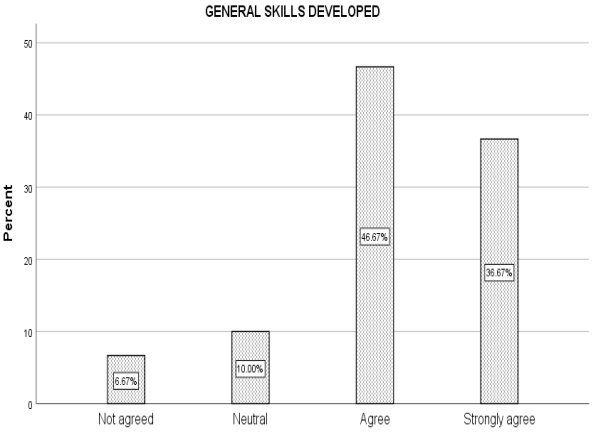
4. Data Analysis and Interpretation

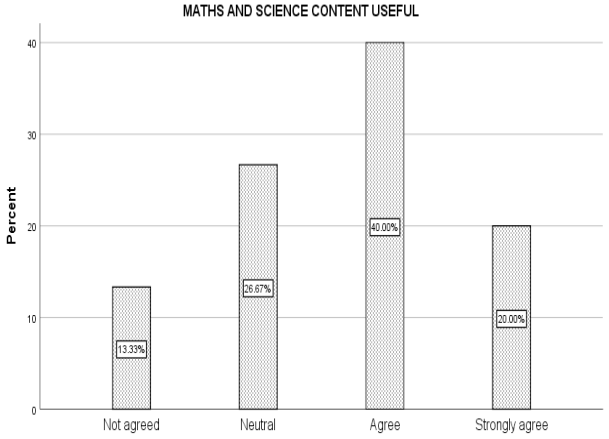
Interview schedule was prepared separately for the students, parents and faculty. Consultations commenced with briefing on the background and purpose of the study. The answers were recorded for analysis. The analysis and interpretation are given in the forthcoming sections.

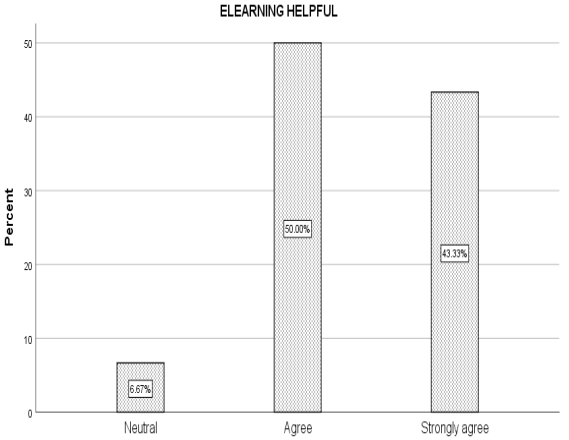
4.1. Perception of Engineering Students

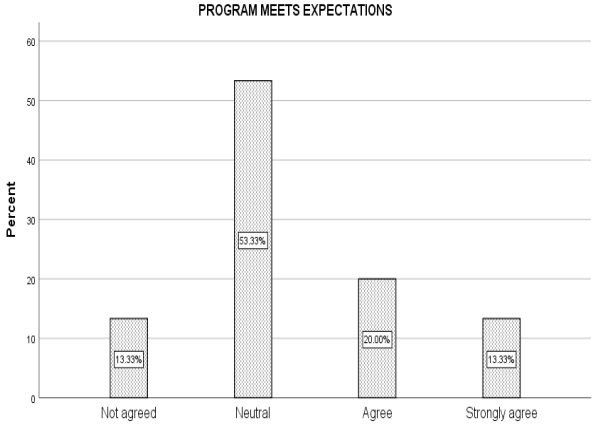
Representative group from all the disciplines were chosen based on systematic random sampling i.e. 2 student representatives from each group, hostel, day scholar, girls and boys from each discipline were called for focus group consultation with a set 15 questions on their perceptions about engineering education. The questions were framed based on King's survey on Australian engineering education in 21st century[10] and National Employability Survey Engineers (Aspiring Minds, 2019) survey on Indian Engineering Education. The questionnaire was validated through a pilot study with select number of students. Consultation with the focus group of students commenced with a briefing on the background and purpose of study and the questions were displayed for discussion. The discussion revealed that the students had varying perceptions on the engineering education. Fig. 1 summarises the responses of the students:

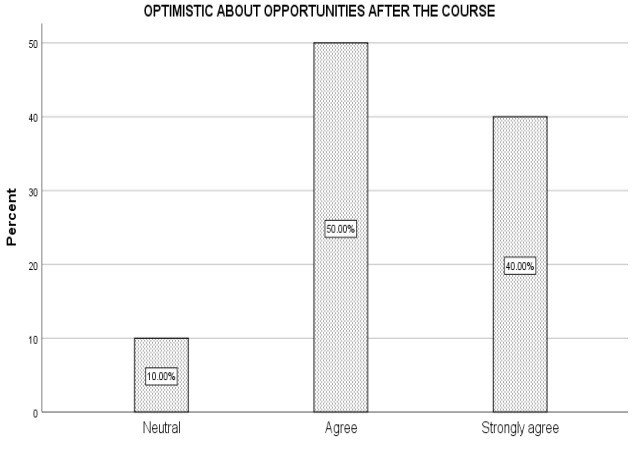

AVAILABILITY OF OPPORTUNITIES TO DEVELOP SKILLS
Percent
80
60
40
20
0
3.33%
23.33%
73.33%
Neutral
Agree
Strongly agree


GENERAL SKILLS DEVELOPED
Percent
50
40
30
20
10
0
6.67%
10.00%
46.67%
36.67%
Not agreed
Neutral
Agree
Strongly agree


MATHS AND SCIENCE CONTENT USEFUL
Percent
40
30
20
10
0
13.33%
26.67%
40.00%
20.00%
Not agreed
Neutral
Agree
Strongly agree


ELEARNING HELPFUL
Percent
50
40
30
20
10
0
6.67%
50.00%
43.33%
Neutral
Agree
Strongly agree


PROGRAM MEETS EXPECTATIONS
Percent
60
50
40
30
20
10
0
13.33%
53.33%
20.00%
13.33%
Not agreed
Neutral
Agree
Strongly agree


OPTIMISTIC ABOUT OPPORTUNITIES AFTER THE COURSE
Percent
50
40
30
20
10
0
10.00%
50.00%
40.00%
Neutral
Agree
Strongly agree

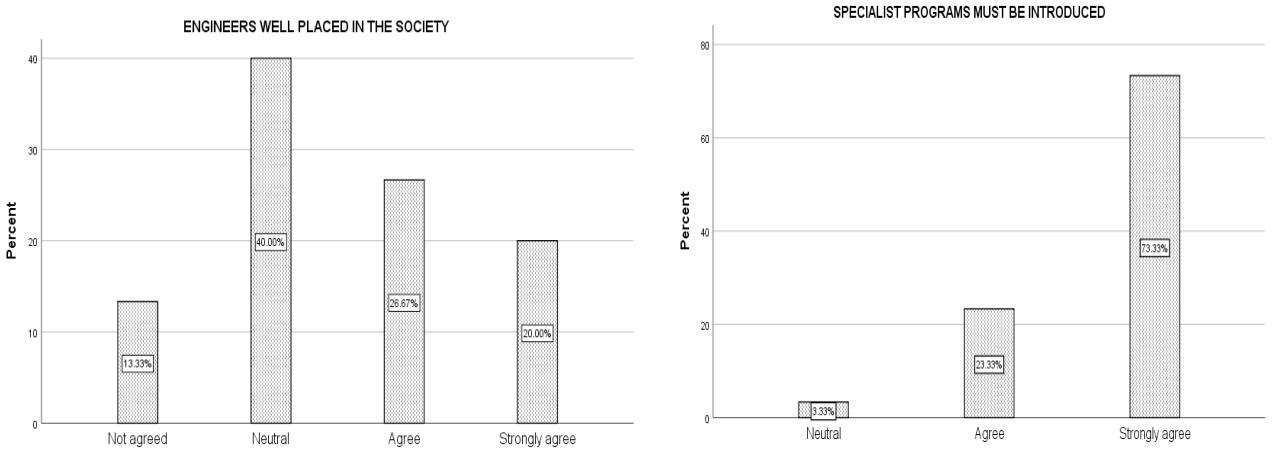


Fig. 1. Summary of Students' Perceptions

The data and the charts reveal the following:

Most of the students are optimistic about the future opportunities after their engineering education but at the same time, more than 50% of them are apprehensive about the position of engineers in the society. Similarly, most of them(>96%) opined that the opportunities to develop skills are plenty in engineering curriculum and general skills such as communication skills, softskills, coding skills and the like are given due importance but the scope for creativity and innovation in the course of study are not very optimistic for more than 56% of the students. Students, in general, are quite satisfied about the educational methodologies adopted (lectures and laboratory classes) but are not very confident about the innovative methodologies used. Mathematics and science content and e-learning options are useful.

When probed on the new age technologies such as Machine Learning, Data Science, Artificial Intelligence, Cloud Computing, IoT, User Interface/User Experience etc., as expected, students perceive that new age technologies are catching up and upskilling in the technologies are in need for the job market. 96% of the students strongly opine that the universities should introduce courses on new age technologies. Though the responses from the students were positive on various aspects of engineering education, only 33% of them are confident about the course and its outcome.

Further questioning on the students' perceptions on their choice of engineering degree, few important insights were revealed:

1. Around 60% of the students chose Engineering for better career and 35% of the students have genuine passion.
2. Parents' choice was given as one of the reasons for choosing the branch of study.
3. Students choose their institution for study based on the placement record, academic record, NBA accreditation, NIRF ranking and NAAC accreditation.
4. Students have different plans after their graduation, 33.6% of the students preferred to work in core jobs (33.6%), 23.6% of them preferred IT jobs, 12.9% of the students would like to opt Civil services and 20.1% of the students would like to pursue higher studies.

Future of Engineering Education- students' perspective

70% of the students are optimistic about the future of engineering education and expressed that engineering would

attract more students in future. With new technologies on the rise, engineering with specialist knowledge only can cope with the job market requirements. With technology dominant industry, engineers are more relevant and find suitable career.

1. There is a myth regarding the future of engineering jobs, students with skills will surely have ample opportunities.
2. Engineering being the core of everything, the future cannot be hampered for engineering education.
3. With more societal and environmental issues and challenges, only engineering can provide the salvation.

But 30% of the students are apprehensive about the future of engineering education. The reasons cited include:

- Loss of interest
- Less job opportunities
- Technology will replace humans reducing the scope for manual job
- Increasing competition
- No value without specialization
- No creativity
- Outdated syllabus
- No practical training by the institutions
- No industry participation.

Overall, students are very positive in their outlook on engineering education but still are doubtful about the outcome of the education. The discussion emphasized the importance of practical training, skill development in emerging technologies, creativity and innovation, project based learning, reframing of curriculum etc.

4.2. Perceptions of The Faculty Members

Faculty members who have more than 15 years of teaching experience in engineering education were chosen for the study. An interview schedule was fixed with a briefing on the background and purpose of the study. The summary of the findings is given below.

All the teaching faculty respondents invariably vouched that the engineering education has undergone a paradigm shift when compared to their time of study. The reasons cited are:

- Engineering education has taken a multidisciplinary approach with a need for self learning and interactive learning.
- Today's engineering education has undergone a change from content based to outcome based learning
- Focus is more on producing industry ready and employable engineering graduates
- Basic concepts are sidelined and high end technologies are given importance.

The change is mainly due to the changes in job market requirements, technology advancements and omnipresent ICT. Similarly, the faculty members perceive significant changes in the mindset of the students over this period and few perceived changes are lack of moral and human values, engrossment in social media and information overload. Such changes may be due to increasing competition, unemployment, growing IT / ITES sector and reduced teacher dependency. These challenges may be tackled by conceptual understanding, industry participation, interdisciplinary projects, practical training and by introducing more problem based learning strategies. Similarly, the need for specialist courses on emerging technologies is perceived to be crucial.

Future of Engineering Education- faculty members' perspective

Albeit, a general positive response regarding the future of engineering education, the major challenges foreseen include lack of expertise in the emerging technologies, infrastructure development and laboratories. Most of the faculty members appraised the need for up-skilling the faculty members in new age technologies.

4.3. Parents' Perception On Engineering Education

Parents form the major stakeholders of engineering education. More than 60% of the students opined the parents' push behind their engineering option. When probed on "the choice of engineering for their ward's career", unanimously they chorused on the job opportunities and better career. In spite of the challenges in engineering education, such as high fee structure, unavailability of courses in dream institutions, distance from residence etc. parents prefer to enroll their wards in engineering education with one and only motive: a better career.

4.4. Industry Requirements

International Labour Organization reported around 75 million is unemployed and three times as many are underemployed. This is mainly because the job market is grappling with education-to-employment gap. Though an engineering degree is not equal to job readiness, the industries look for employable and job ready students with 21st century skills (Weichert, B. et al., 2001). Some of the skills cited by the recruiters include: Critical thinking, Creativity, Collaboration, Communication, Technology, Information literacy, Flexibility, Leadership, Pro-activeness, Productivity and Social skills.

Students with the above said skills are more preferred in the job market compared to the ones with mere academic performance. And above all, learnability is viewed as one of the top ranked skills, which means the illiterate of 21st century would be the one who cannot learn, unlearn and relearn (Alvin Toffler, American writer). Traditional Recruitment processes include testing of communication skills (written and oral skills), technical knowledge, coding skills and attitude. Mass placements by IT and ITES companies may no longer be viable in future and predict the technology intervention for recruitment. Technology adaptations in recruitment is widespread in today's scenario, for example, automation makes recruitment better in terms of wider reach, better decision and time saving [18]. Also, placement officers opined that participation in corporate contests such as Hackathons, Idea contests, Project contests etc. may be a source of recruitment. Placement officers perceive that future of recruitment will be based on participation in Corporate contests such as Hackathons, Idea contests, Project contests etc. Recruiters like to cut on their cost of hiring process and are opting to have "Day 1 billable" employees. Also, students would be expected to have specialist knowledge in Automation, Industry 4.0, IoT, Artificial Intelligence, Cyber Security etc.

Cognizant [5] lists down "21 jobs for future" that will emerge over the next 10 years and will become cornerstones of the future of work such as, Edge Computing, Quantum Machine Learning Analyst, Augmented Reality, AI Based Systems, Data Detective etc. Though it is perceived that in future, "Gig" economy will set in (full of temperory jobs), need for human intelligence can never be overseen.

5. Recommendations

Based on the extant literature and the study, few suggestions are made for making Indian technical education more robust.

Recommendation 1: Enhancing the teaching – learning process

Adopting innovative teaching-learning process is crucial in making the students interested in engineering education. Few of the important changes that may be brought in this aspect are:

- Revision of teaching – learning pedagogies by incorporating innovative teaching practices for enhancing the learning experience
- Learner-Centric teaching practices
- Emphasis on outcome based education
- Partnerships between industry and institutions, institutions-institutions, institutions – professional bodies
- Creation of research culture
- Exposure to current industrial practice
- Provision to foster innovation and creativity etc.

Recommendation 2: Up-skilling the faculty members

Teachers are the pillars of any education system. Enhancing the quality of the teachers will have direct and profound impact on the students' learning skills. While school teachers and Arts & science college teachers qualify in Teachers entrance test (TET), NET (National Eligibility test), SLET(State level eligibility test) etc., such qualifying examinations to work in engineering colleges are not available. In 2019, Prof. Anil Sahasrabudhe, Chairman, AICTE announced that the technical teachers also have to undergo a eight week training on "Orientation towards Technical Education & Curriculum Aspects"; "Professional Values, Ethics, Ecology & Sustainable Development"; "Communication Skills, Modes and Knowledge Dissemination"; "Instructional Planning and Delivery"; "Technology Enabled Learning and Life-long Self-learning"; "Effective Modes of Student Assessment and Evaluation"; "Creative Problem Solving, Innovation and Meaningful R&D and 3 weeks of internship. This will definitely improve the quality of technical teachers. Hence training and skill development of the faculty members should be taken as the first priority to enhance the quality of engineering education. Few measures that may prove beneficial are:

- Training of faculty members
- Inculcating research culture
- Online course certifications
- Faculty development programs by the industry on specialist courses
- Periodical refresher courses
- Enhancing communication skills and
- Motivation

Recommendation 3: Enhancing students' attitude and participation

The ultimate beneficiaries of all the measures are the students. The changing mindset, information overload, lack of attitude and aptitude, social media distraction etc. should be addressed through appropriate measures such as, counseling, mentoring, innovative teaching pedagogies etc. Most of faculty respondents have also emphasized the need for value based education. This may be achieved by implementing the following measures:

- Innovative teaching-learning process (Recommendation 1)
- Professional ethics education
- Integration of human and moral values to boost the attitude of the students
- 5-10 day orientation programme for the freshers by the senior students, Alumni and industry
- Emphasis on project based learning, internships, collaborative learning.
- Introduction of specialist courses
- Awareness on changing job markets etc.

Recommendation 4: Upgrading the curriculum and facilities

Policy makers, Universities, academic heads and management (in case of private institutions) are the four important pillars for bringing in the changes recommended above. Unless the changes are brought in terms of curriculum and syllabus to suit the current needs and the required infrastructure d, attaining the goal of "Enhanced quality of Engineering Education" will only be a dream. The changes that are recommended in this aspect are:

- Introduction of scope for general skills development
- Scope for research and project based learning
- Scope to foster innovation and creativity etc.

- Education on 21st century skills
- Revision and updation of syllabus and curriculum periodically to suit the global scenario
- Development of infrastructure
- Appointment of qualified faculty members etc.

The proposal, if implemented effectively by all the technical institutions, the standard of technical education might see a tremendous growth.

6. Conclusion

Education is the art of preparing the individuals with skills and overall development. University is a place where creative minds converge and ideas germinate [19]. An empirical survey to understand the perceptions of stakeholders of engineering education was carried out through focus group consultations. In general, students have mixed perceptions on the engineering education. But most of them were optimistic on the future of engineering education and the parents' major motive behind choosing engineering for their ward's career is the availability of job opportunities. Faculty members also expressed positively on the future of engineering education but were apprehensive on the students' mindset.

Overall, international competition, changing global scenario, expectations of the job markets and advent of new technologies pose challenges and necessitates the analysis of the existing curricula and their relevance to the world in future. Hence there is great need to shift the focus of higher education institutions, technical teachers, and the universities to update and construct curriculum to enhance 21st century skills.

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