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Strategies for Promoting Globally Competitive Engineering Education in India

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Abstract : In the last ten years, there is a growing chorus of discontent about what is not happing in the engineering education in India. Around 5 % of the engineering graduates are possessing required industry -relevant skills and competencies. All over the world major efforts are being undertaken to transforming the engineering education. Based on the research, it is suggested to improve the performance of the faculty members, their abilities to undertake the globalization of engineering education and digitalization. Further there is a need for improving the faculty development through flexible and blended programs under NITTTRs, NITs, State Technical Universities, modernization of curricula and instructional design and collaboration with the industry and government. The colleges are to network with well performing global universities and collaborate in research and development. There is an urgent need for Institute-Industry-Government Partnership for improving the curriculum, research methods and product innovation. The institutes can review their curriculum through Faculty-Alumni-Industry-Representatives of Entrepreneurs (FAIR) Committee once in a year and make improvements. The engineering students are to be exposed to the problems of the industries and they are to be coached to solve them. Their research work, dissertations have to be industry relevant. Further, the engineering institutes have to plan innovative products as a part of the capstone projects. Ultimately the Indian engineering education has to develop industry relevant competency model which will focus industry relevant skills and competencies.

Keywords: Competitive Engineering education, flexible curriculum, blended programs, sponsored research and development projects.

1. Introduction

Most of the world leaders in engineering education are constantly focusing on the impact of ICT, IoT, digitalization, vulnerability, uncertainty, complexity and ambiguity in the design of high- end engineering programs. The manufacturing sector takes back seat to research and development, services and information and communication technology.

Literature Survey

Peter Smith (2008) stated that Americans are failing to educate large number of students in higher education successfully because they are employing an out-of-date educational model that ignores the knowledge and resources available that would make their students successful. In keeping with strategic

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objective of offering a globally competitive engineering education, many American universities established exchange programs in Asia and Europe.

Korean Universities immerse their students in today's global challenges to help them think accurately and discern clearly, the paths they wish to follow if they are to lead future generations.

Indian students are lagging far behind the global standards. Only 5% of them get jobs in MNCs. These problems need to be investigated and suitable remedial measures are to be identified. The competitiveness of the economy largely depends on the human and knowledge capitals.

Most of the researchers in the advanced countries have focused on the problems due to fast growing digital technology (Albert Kamp, 2016, David Beanland and Roger Hadgraft, 2013, Graham Davis et al., Michael Basis, 2015, and Shannon and Shari, 2016). There is a need for additional funds for research. Further the faculty members need to be encouraged to under go MOOCs in content updating and andragogy. There is a also a need for establishing national universities for developing and implementing MOOCs. The Bologna Process makes use of European Credit Transfer and Accumulation System. Flexible programs designed to accumulate credits and later to get postgraduate degrees.

Construction firms in India have spent the past decade focusing on Indian market, steadily building up cash positions and internal experiences. Now they are expanding outward and seeking to compete against established global players. This gives rise to more demand for well- trained Indian building technologist and engineers. Hence the building technology programs should be developed to global standards.

Erik Hallebrand and Wilhelm Jakobsson (2016) the design of high-rise building. Rupali Kavilkar and Shweta Patil (20140 focused on the study of high-rise residential buildings in Indian cities.

High-rise buildings are exposed to both static and dynamic loads. Depending on the method used and how the structure is modelled in finite element software the results can vary. The variation in static results from reaction forces, overturning moments, deflections, critical buckling loads, forces between prefabricated elements and force distributions between concrete cores are to be investigated with different models. Ahmed Cherif Megri (2011) suggested that plumbing design for high-rise buildings.

Some of the advanced technics are to be included in the curriculum are as follows:

- Green buildings
- Stability of high-rise buildings
- Analysis for seismic retrofitting of buildings
- Earthquake vibration control using modified frame-shear wall
- Seismic isolation devices
- Energy dissipation devises for seismic design
- Advanced earthquake resistant techniques
- Smart materials
- Prevention and repair of cracks in structures
- Corrosion mechanism, prevention and repair of RCC structures
- Non-destructive testing of concrete
- Rehabilitation techniques
- Advance construction techniques
- Mineral admixtures for high performance concrete
- Glass fiber reinforced concrete
- Deep foundation design
- Machine Foundation
- Shallow foundation design
- Ground improvement techniques
- Geosynthetics

The UK engineering base has a world-leading position in a range of the knowledge-intensive industrial sub-sectors responding to global challenges, as well as in the scientific and

technological research and innovation that underpin them. The recommendations of UK Engineering Firms are:

- Increase the supply pipeline of engineers from education
- Increase diversity
- Increase the supply of skills through the workforce
- Maintain the international dimensions
- Focus on the Industrial Strategy

Many engineering firms in UK are struggling to recruit graduates, since, the graduates are lacking hands on experience.

A group of UK consultants identified the biggest skills that new graduates lack: Communication and Problem- Solving Skills.

According to US Chemical Engineers the chemical engineering graduates in USA are not able to meet the skills prescribed by Chemical Process Industries (CPI) since the curriculum has not been updated. The Chemical Industry Experts evaluated the skill gaps and listed the following skills to be included in the chemical engineering curriculum:

- Process or Operation Optimization
- Statistical Analysis and Experimental Design
- Physical Process Modeling
- Statistical/Empirical Dynamic Process Modeling
- Multivariable Interactions and Multivariable System Analysis
- Statistical Process Control and Process Monitoring
- Proportional -Integral-Derivative (PID) Loop Design and Turning
- Nonlinear Dynamic and Nonlinear System Analysis
- Frequency Domain Analysis
- Expert System and Artificial Intelligence

In addition, these consultants stated that the students should receive hands on experience to practice process control as it is implemented in industry.

Further, they desired that the chemical engineers in industry and academia must continue conversation to better align core curricula in undergraduate programs with skills that are needed now, as well as to anticipate the skills that will be needed in the future.

It is needed to evaluate all other core courses of other branches and identify the gaps. The prescription would be highly useful to improve the desired skills and competencies of the graduates of that branch.

Many of the traditional engineering programs in Civil engineering, electrical engineering and mechanical engineering need to be bifurcated or trifurcated to meet the industrial needs.

Engineering Industry Competency Model Developed by American Association of Engineering Societies

American Association of Engineering Societies (AAES) and the U.S Department of Labor (USDOL) have developed an Engineering Competency Model (ECM). This model consists of 5 tiers and are presented below:

Tier 1-Personal Effectiveness Competencies

This is composed of interpersonal skills, integrity, professionalism, initiative, adaptability & feasibility, dependability & reliability, and lifelong learning.

Tier 2- Academic Competencies

This is composed of reading, writing, mathematics, science and technology, communication, critical analytical thinking and computer skills.

Tier 3- Workplace Competencies.

This is composed of teamwork, client stakeholder focus, checking, examining and recording and business fundamentals. planning and organizing, creative thinking, problem solving, decision making, seeking and developing opportunities, working with tools and technologies, scheduling and coordinating.

Tier 4- Industry-Wide Technical Competencies

This is composed of foundations of engineering, design, manufacturing and construction, operation and maintenance, professional ethics, business, legal and public policy, sustainability & societal and environmental impact, engineering economics, quality control & quality assurance, safety, health, security and environment.

Tier 5- Industry-Sector Functional Areas

This is composed of competencies to be specified by industry sector representatives, management competencies and occupation-specific requirements.

Interpretation

The faculty members have to focus on the performing skills to reach the industrial standards prescribed by the accreditation organizations like ABET.

Many executives of industries express that Indian engineering students need more exposure to the Industry-Wide Technical Competencies.

To acquire Workplace Competencies, the students have to be exposed to the current industrial practices in product design, prototype development, testing, product improvement and mass production and maintenance. They need to visit at least one industry per month in the sixth semester.

To acquire Industry-Wide Technical Competencies the students need internship in a company for about three months.

When the graduates join the companies, they have to be exposed to Industry Sector Functional Areas as a part of the induction program of the company.

Leslie (2016) elaborated the Engineering Competency Model (ECM) which serves as a guide for development of professionals in the engineering workforce. ECM provides a career ladder/lattice for engineering profession and promotes an understanding of the skill sets and competencies that are essential to educate and train a globally competitive workforce. This competency model for engineering will serve as a resource to inform discussions among industry leaders, educators, economic-developers, and public workforce investment professionals as they collaborate to identify specific employer skill needs, develop competency-based curricula and training models and certifications.

American universities provide institutional support for faculties, they have added cross-campus initiatives to promote pedagogical innovations, curriculum reform and redesign, assessment, interdisciplinary work, periodical accreditation and leadership and organizational development work (Deborah De Zure et al., 2012).

Advances in Mechanical Design revolutionized Production Technology and Industrial Engineering (Anton Van Beek, 2016; Jianrong Tan, Feng Gao and Chiangle Xiang, 2017; Marco Cercarllia, 2018). Fail Safe and Stress Analysis, Dynamic Analysis and Control, Vibrations Material Technology, Computer aided analysis of manufacturing process, Analysis and design of mechanical systems and components have become essential for the mechanical engineers. Hence the mechanical engineering curricula have to be updated.

Objectives Of The Research

- To assess the gross deficiencies in the current engineering students by matching the desired and industry specific competencies.
- To plan faculty development programs through the senior industry executives based on the long-term cooperation agreements.
- Develop the students to meet the industry relevant competencies and the desired skills prescribed by the accreditation agencies through planned industrial exposures.
- To validate the improved curriculum through a small group of Faculty-Alumni-Industry experts, and Recruiters (FAIR).
- To develop an Industry Specific Educational Qualification Framework (ISEQF) for engineering students for implementation.

Research Methodology

A series of three days faculty development programs have been organized in the areas of Institutional Development, Creation of Centers of

Excellence, Performance Improvement and Industry-Institute-Government-Partnership Development. Around 180 senior faculty members (heads of departments and vice-principals) have been invited and participated. They were given the following set of four problems to solve through quality circles:

1. Improving the Quality of the Faculties,

2. Improving the Skills and Competencies of the Graduate Engineers

3. Improving the Human Capital to Meet the Challenges of the Fast- Growing Indian Industries

4. Institutional Development

Outcome Of The Quality Circles

The following are the major suggestions from the Quality Circles:

Gross Deficiencies of the Engineering Graduates are:

· They have many knowledge gaps in design, analyses, prototype development, testing and improving the product, mass manufacturing, and maintenance.

- Not having sufficient expertise with respect to workplace

- Not having sufficient expertise with respect to industry- wise technical competencies.

Gross Deficiencies of the Engineering Faculties

- Not having industry experiences

- Many do not possess Masters and Ph.D. in engineering

- · Most of them have not undergone faculty development programs in curriculum design, formative evaluation, summative evaluation, instructional design and delivery, undertaking sponsored research and development projects, strategic planning, institutional development, publication of research papers, planning and implementing continuing education programs, planning tracer studies of graduates, conducting impact studies, and conducting research in the interdisciplinary areas.

- Not having experience in planning and implementing in global projects

- Not having in- depth expertise in innovative product design, prototype development, testing and refinement.

- Not having cognitive abilities to undertake innovation.

Gross Deficiencies in the Indian Institutes

- Limited highly qualified and experienced faculty

- Poor infrastructure

- Not having sufficient linkages with the industries

- Limited equipment, tools and instruments in the laboratories and workshops

- Limited smart class rooms

- Only 50 % of the faculty on role

- Faculty to student ratio is 1:30

The group of senior faculties have formed a quality circle and brought out the following measures:

1. Improving the Quality of the Faculties

- Introduce sequential summer and winter schools for the faculty development in the digital technologies, advances in the analyses, design, prototype development, testing, mass production and maintenance.

- Provide more institutional development funds, to expand the laboratory resources, workshops and industrial links for quality improvement.

- Increase the salary of the faculties and provide grants- in- aid for their planned industrial exposure, and undergoing MOOCs.

- Introduce blended programs based on the new MOOCs for faculty development.

- Expose them to the design, product development and mass production of innovative products in the industries.

• Prepare competency maps to match the engineering quality framework desired by the industries for the students which are relevant at entry and middle-levels jobs.

• Cultivate research and development competencies of the faculty members to undertake industry sponsored projects.

• Decrease the ratio of the teachers with that of students from 1: 30 to 1: 16.

• Invite adjunct faculty from the companies to offer courses in the current industrial practices.

2. Improving the Skills and Competence of the Graduate Engineers

• Evaluate learning outcomes against the standards of accreditation and improve the students' competencies to match the National Engineering Qualification Framework.

• Introduce blended programs based on the new MOOCs for students' development and equate to regular courses.

• Develop global curriculum to meet the needs of MNCs.

• Introduce dual programs so that the outstanding students can take up desired industry jobs and postgraduate programs.

• Constantly improve the programs based on the annual evaluation through longitudinal studies and tracer studies of the alumni.

• Offer knowledge- based internships in the seventh semester for two months and offer around six credits and provide assistanceship through the Board of Apprenticeship Training.

• Check the accreditation standards of ABET and encourage maintenance of high academic outcomes

• Develop and mass produce the validated case studies.

• Introduce case studies based on the current industrial practices.

• Use relevant video programs to supplement the printed materials.

· Offer industry specific projects and dissertation works.

3. Improving the Human Capital to Meet the Challenges of Fast- Growing Indian Industries

• Increase the intake in the PhD programs through various NITs, IITs, Autonomous Engineering Colleges and State Technical Universities.

• Establish a National Quality Improvement units in the Institutes which can coordinate all the industrial collaborations.

• Establish an unit for Learning Outcome Research and Development and preparation of Advanced Learning Packages.

• Refine the programs to meet various cadres of the jobs like design engineers, manufacturing engineers and maintenance engineers.

• Make transformation of the engineering institutes through digital technologies.

• Employ experienced design engineers as adjunct faculties to guide both the faculty members and graduate students.

• Develop industry specific and flexible research projects as dissertation topics and fund the project.

• Publish the completed projects as learning materials.

4. Institutional Development

• Encourage cooperation and collaboration of the industry and national labs.

• Eliminate the barriers to change.

• Convert all NITs and NITTTRs as the Institutes of National Importance. And provide additional staff for development works.

• Close down poorly performing institutes.

• Maintain high standards in the approval of the new institutes.

• Encourage global networking with research universities.

- Create a culture of blended learning both for the faculties and as well as for students

- Develop industry specific curricula in collaboration with the industry

- Introduce learning accountability.

Faculty-Alumni-Industry-Recruiters (FAIR) Consultation Meeting

It is possible to get a clear view of the gaps in the ongoing curriculum and the skills needs of fast-growing Indian industry through a working group meeting of the following stake holders:

1. Faculty who plan the curriculum,

2. Alumni who completed the program and actively working in the industry,

3.Industry executives who assign various tasks like design, analysis, prototype development,

4. Representatives of campus recruiters.

The faculty can present the highlights of the ongoing industry relevant curriculum and the planning for changes/improvements.

The alumni can provide authentic feedback on the curriculum and present the current needs in various courses and workshop and laboratory practices.

The executives who assign various professional jobs to the recruited graduates can give their appreciation and their expectation of skills and competencies from the new graduates.

The representatives of the recruiters can provide their overall skill profile, and other soft skills needed.

The faculty can incorporate the suggestions and prepare a draft curriculum. All the suggestions are to be validated through a Faculty-Alumni-Industry representators and Recruiters (FAIR). The collaboration with the industry, the Ministry of Industries and the Ministry of Human Resource Development will ensure the quality. Online feedback can also be collected from alumni and the executives of industry.

Industry Specific Educational Qualification Framework (ISEQF)

For each industry qualification framework needs to be developed.

1. Professional Skills and Competencies

Professionalism, project specific knowledge, contextual knowledge, lifelong learning in the branch of engineering, integrity, intellectual skills, higher order cognitive abilities in planning, design, estimation, desired interpersonal skills, project initiatives, technical dependability, adaptability to the technology, workplace, ethics, project specific knowledge, attitude, and excellence.

2. Higher Order Cognitive Competencies

These include the project specific analyses, safe design, optimum estimation, detailed specification, preparing detailed drawing for plan, elevation, sections, fabrication/construction/manufacturing, testing and certification, evaluation of bids against terms of reference, evaluation of technical proposals, cost effective project management, and return on investments.

3. Workplace Competencies

Formation of high-performing teams, planning and organizing the jobs and tasks, problem solving, creative thinking, conflict resolution, leadership, guidance, critical path methods, site organization, 5 S, following rules and standards, pollution control, scheduling the works, quality control, productivity, safety, energy management, decision making, interpersonal relations, planning job aids, measuring and workbook maintenance, online data logging, bill preparation, check measurements, communication, performance improvement, etc.

4. Industrywide Managerial Competencies

Interdisciplinary and multidisciplinary approach, strategic planning, advances in the design, cost effective products, value analysis, selecting new approaches, computer assisted design, economics, cost of return, project management, sustainability, and innovation.

5. Industry-Sector Functional Areas

Global perspectives, taking national and global projects, global leadership, excellence in transformation through innovative products.

establishing sustainable projects in various countries under WTO,

National Policy on the Transfer of Credits Earned through Apprenticeship Training and Internship

There is a need for a national policy which will accelerate engineering work force development initiatives. The industries could focus from the Companies' Social Responsibility (CSR).

The faculty development has to be accelerated to meet the growing challenges through appropriate faculty development through industry.

The MOOC have to be given importance in the faculty development. There is a need for focus on the digital technology.

Periodically review the Indian Engineering Program Development with those of global universities. Constantly improve the standards the quality of the faculty and as well as that of engineering students.

Hence, there is a need for continuous improvement in the curriculum and its implementation.

Conclusions :

The transformation of the Indian engineering education has to be considered by developing the faculty, improving the curricula, improving the skills and competencies of the graduates.

It is very important to establish an Institute for Learning Assessment in Engineering and a National Quality Improvement Institute in Engineering and Technology. The trained faculty will be continuously conduct research and suggest improvements.

Introduce more internship programs under the Board of Apprenticeship Development. Encourage keystone projects which are relevant to society.

Elevate well performing NITs and NITTTRs as the Institutes of National Importance so that they can undertake multidisciplinary research and development, faculty development, mentors for the engineering faculty members.

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