IMPROVING ENGINEERING EDUCATION IN INDIA USING INFORMATION AND COMMUNICATION TECHNOLOGY: A NEW FRAMEWORK

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ABSTRACT
Given the current scenario of engineering education in India, there is a dire need of improvement in the way engineering education is structured and the guidelines it follows. With Information and Communication Technology (ICT) having become accessible and widespread, it is bound to play a vital role in enhancing the state of engineering education. The existing structure and framework of engineering education and its surrounding ecosystem have been studied in great depth. The paper proposes a new framework for engineering education using ICT. A generic level component breakup for engineering will be made, followed by detailed description of each component, again on a generic level. Each detailed description has been followed by ways of executing them based on different branches of engineering. The entire engineering education scene needs to move towards a self-learning environment which is totally lacking in today's faculty dependent model. The new framework components along with the guidelines will pave the way for a self-learning environment based model for engineering education. It will be a founding stone for ICT based initiatives in engineering education in India.

Keywords: Engineering education, framework, information and communication technology

1 INTRODUCTION
There is a dire need to improve the quality of engineers being produced in India. The number of engineers and the engineering colleges are increasing at a very high rate. Currently third in the world, we will soon be only second to China in terms of producing one of the highest number of engineers in the world [1][2].

Table 1. Increase in engineering colleges and student intake for past 15 years in India

	1996	2006	2008	2010
Total number of engineering colleges	416	1511	2297	*3000+
Total intake	1, 01, 451	5, 17, 018	*6, 00, 000+	*7, 00, 000 +

**predicted*

In the current system of engineering education students are heavily dependent on the faculty. There is a lack of a self-learning environment. The students have access to projectors, computers and Internet in the engineering institutes but not the best means to exploit these resources. ICT is a strong contender that can ride on these basic resources and prove to be an effective catalyst in the change required in the way engineering education is currently being imparted and structured.

2 RESEARCH METHODOLOGY
- Studied engineering curriculum documents for engineering disciplines by AICTE [3] [4] [5].
- Curriculum and content structure of a few engineering colleges were studied [6] [7].
- Group discussion sessions were held with engineering students.
- Qualitative interviews were conducted with engineering students from different colleges in person, over the telephone and through emails.
- Experiences from my own journey as an engineer were re-collected.

3 EXISTING FRAMEWORK

3.1 What does it currently consist of?

The current engineering education system revolves around three major components defined by AICTE [8]. They are:
1. Lectures (47%)
2. Practical (35%)
3. Tutorials (18%)

The entire curriculum for all engineering institutes is designed on these three components and the time period of the engineering classes is divided according to the weightage given to the above components. Lectures encompass the classroom teaching that currently happens mainly through the following media:
1. Faculty using chalk and board
2. Faculty speaking
3. Faculty reading from PowerPoint slideshows (seldom)

This makes the entire system dependant on faculty.
Practical encompass the laboratory work and the projects that the students take up.
Tutorials encompass the assignments and quizzes. Assignments are mostly question and answer based.

3.2 What are the key issues?

Key issues are based on insights derived from user studies with engineering professionals, students and faculty; and the findings arrived at while studying the existing framework and curriculum.

- Absence of a self-learning environment.
- Heavy dependence on faculty, most of them are not up to the mark as they are fresh graduates.
- Rote learning is promoted, students study only to pass in the exams.
- Current framework has got very limited and restrictive components - Lectures, Practical, Tutorials. The changes being proposed by various committees are within the bounds of it and the complete skill set that an engineer requires is getting ignored.
- Most part of a student's time is spent in the classroom, which comprises of monotonous and boring lectures.
- Most of the engineers do problem solving in the industry where new problems and scenarios keep on coming which requires new and creative solutions. But, while in college, no stress is laid on problem solving and creative approaches.
- Not enough emphasis is laid on working in teams and coordination. Interdisciplinary knowledge is poor amongst students. Whereas in the industry, engineers work mostly in inter-disciplinary teams.
- Presentation and communication skills are ignored. In the industry, engineers constantly communicate with their team-mates and frequently present their ideas and solutions to seniors, clients or team.

4 ROLE OF ICT IN ENGINEERING EDUCATION

4.1 What is the current scene?

- Most of the engineering institutes have access to projectors, computers and Internet.
- Faculties make seldom use of slideshows during classroom teaching. It is mostly a unidirectional presentation.
- There is a lot of free content related to various engineering disciplines on the web.
- Currently students hardly make use of this free engineering content on the web as it is scattered, not available through a single well-structured platform and there is heavy dependence on the faculty for learning.

4.2 What can be best explained using ICT?

The content and curriculum of engineering education was studied and the areas that can be explained in a better way were evolved by affinity mapping and card sorting. They were divided into two main sections on a generic engineering scale. The areas which can be explained in a better way using multimedia rather than the traditional methods of teaching are:

1. Using video and animation
- Functioning and working of devices.
- Application of devices, equipment, software and methodologies.
- Process of fabrication, data transfer, manufacturing, production and assembling.
- Model making.
- Explaining scientific phenomenon in physics, chemistry, and biology.
- Explaining change in the behavior/properties of devices, equipment and materials.
- Video lecture by an expert or a faculty.
- Cultivating interdisciplinary understanding.

2. Using slideshows
- Dynamic and static diagrams which include charts, flow, schematic explanatory, structural, process based, state, network, phase change, decision, layout and comparison diagrams.
- Actual/real images of devices, equipment, defects, faults and change in properties.
- Explanation of concepts.
- Explaining graphs. They can be made dynamic.
- Data representation, comparison of experimental results.
- Giving a quiz or assignments.
- Explaining equations, formulas and derivations.
- Explaining algorithms.
- Summary of a lecture, giving references and web links.

5 ROLE OF AN ENGINEER IN THE INDUSTRY

5.1 Process followed
- Multiple industrial websites related to different sectors were studied to explore the job descriptions for an engineer.
- Interviews were carried out in person and over the phone with engineering professionals from different disciplines.
- The aim was to arrive at major domains under which engineers work and deduce components and skills needed to be imparted to an engineer so that she/he is ready for industry.

5.2 What are the work domains for an engineer?
- Analysis
- Design
- Development
- Entrepreneurship
- Logistics
- Maintenance
- Management
- Manufacturing
- Marketing
- Operations
- Procurement
- Production
- Quality assurance
- Research and Development
- Supply Chain
- Testing

5.3 What does an engineer require in the industry?
Peers: Team work and coordination
Seniors, Clients: Presentation and communication skills
Work: Problems solving and creativity, Professional ethics
Society: Value system and morals

6 ICT ENABLED FRAMEWORK

6.1 Process
A top down approach has been followed. Major components required to be imparted to an engineer have first been identified on a generic level. Each of these components has been further broken down into sub-components on a generic engineering level and not being branch specific. It has been supplemented with guidelines of how to implement each sub-component.

6.2 What are the proposed components?

There are as 6 major components identified and proposed, which are as follows:
1. Theory
2. Practical knowledge
3. Problem solving and creativity
4. Teamwork and coordination
5. Presentation and communication skills
6. Value system and ethics

Multitude of information sources were used to arrive at the improvised framework and examples:
1. Engineers pursuing their under graduate and post graduate degree in premier institutes.
2. Engineers currently employed in the industry.
3. Professors teaching in premier engineering institutes.
4. Reports by AICTE, NKC and others on engineering and higher education in India [9] [10] [11].
5. Statistics on engineering graduates and higher education across the country and relative comparison with a few other nations [1].
6. Websites of a magnitude of companies that hire engineers.
7. Websites providing educational material related to engineering.
8. Websites of selective engineering institutes across the world.
9. AICTE's existing attempts of using ICT in engineering in India [12].
10. Books on various related subjects [13] [14].
11. My own experience while studying Bachelors of Technology.

7 THEORY

7.1 Introduction and basic break up

Theory has been constrained to mainly unidirectional and boring lectures by the faculty in the classroom. Chalk and board being the norm; with read out aloud slideshows being seldom used.
The current framework classifies this section as lectures and has a separate tutorials section which encompasses the assignments. As classroom lectures and assignments are an integral part of learning theory, they have been included under the header of theory. Also, discussions which should be an integral part of classroom teaching are missing altogether in the existing framework. No guidelines exist for how should the assignments be. Currently assignments are very question and answer based and hence the interest level and learning of student is very low. There is also lack of discussions on these assignments in the classroom. With so much advent of the Internet and large scale availability of web resources, it seems that there is a definite way to change this lopsided trend. Certain multimedia resources can be integrated in classroom teaching and certain can be made independently available for students to refer and revise. Taking these factors into consideration the theory section has been divided into three major components:
1. Classroom environment
2. Web resources
3. Assignments

7.2 Guidelines

7.2.1 Classroom environment

- Faculty should promote discussion oriented sessions rather than unidirectional speaking.
- More practical and real world examples to be given to students to make concepts more clear.
- Faculty to promote students to ask questions in the lecture.
- A dedicated doubt clearing session needs to be there towards the end of every lecture. In this session students will ask doubts and the faculty or other students are free to answer them.
- Unnecessary writing on the board should be avoided. For time consuming diagrams, statistical data charts and tables, lengthy derivations the use of slideshow is suggested.
- Assignments should be discussed in the class rather than just taken as a submission.
- Occasional discussion sessions with industry experts on new trends and technologies need to be arranged. It will help students to keep a track with what is going on in the industry

7.2.2 Multimedia resources

- Multimedia presentations involving videos and slideshows should be used where ever necessary. It makes the class interesting and helps in explaining the theory in a better way.
- A bank of multimedia resources should be built by the faculty over a period of time to aid in teaching. This can be in the form of web based resources or self- made videos/slideshows.
- A collection of web based resources can be made available to students which they can refer any time they want. This encompasses tutorials which include notes, examples and problems, multimedia resources as mentioned above, e-books and online journals.
- The areas which can be explained in a better way using multimedia rather than the traditional methods of teaching are covered above.
- Slideshows with voice over by faculty can be made available to students for revision.
- Short snippets of faculty giving demonstration can be recorded and can be either embedded in the above mentioned slideshow or made available independently to students.
- Online forums can be setup where the students can post their doubts and get answers from their peers. Also, concepts can be discussed on these forums. The forum can be administered by either the concerned faculty or a student.

7.2.3 Assignments

- The assignments given to students form an integral part of learning theory. Subjective and objective question and answers are a must.
- Reading assignments based on reference books, journals, articles, IEEE/white papers and case studies need to be given.
- Inclusion of open ended questions needs to be done in the assignments.
- It encourages students to think for a solution in different ways and not stick to only the traditional methods taught. Open ended questions can be research based or theory based.
- Inclusion of re-design problems also needs to be done. These problems can be based on improving the efficiency of a device, change in context for a given device/application and change in tool/platform for a device/application.
- Problem formulation questions need to be incorporated in the assignments. It will help as a student can make good questions only if he/she has understood the subject matter well.
- The assignments need to be discussed in the class with the faculty and other students. This slot can be towards the end of the lecture.

8 PRACTICAL KNOWLEDGE

8.1 Introduction and basic break up

In the current framework under use practical exists as a component. Yet the kind of projects and internships that an engineer takes up has not been explicitly stated till now. The practical section has not been further divided into detailed sub-components. Practical knowledge is an important part of the learning experience for the engineer. It helps them to have hands on experience of how to apply their technical knowledge to solve problems. This section has been divided into 2 major sub-components:

1. Laboratories
2. Projects and internships

9 PROBLEM SOLVING AND CREATIVITY

9.1 Introduction and basic break up

In the current framework there is no provision for problem solving and creativity. Whereas in the industry, most of the engineers do problem solving. The engineers also need to develop good creativity skills in order to be able to solve new problems and problems based in a previously non-encountered scenario or context. Though being the crux of engineering, this section has not been included in the current basic framework. This section has been divided into 3 major sub-components:

1. Analysis
2. Synthesis
3. Creativity

9.2 Guidelines

9.2.1 Analysis

- Dedicated time slots need to be allocated to impart these skills to the students. Analysis has been further divided into two sections:

  1. Analysis that aids in decision making
     - Functional analysis
     - Gap (need) analysis
     - System analysis
     - Value analysis
     - Alternative analysis
     - Decision tree analysis
     - Contingency (if-then) analysis
  2. Analysis that aids in assessment
     - Industry analysis
     - Competitive analysis
     - Data analysis
     - Requirement analysis
     - Market analysis
     - Sensitivity (what-if) analysis
     - Structural analysis

- Use of industry case studies, practical examples and problem solving assignments is recommended to impart the above mentioned analytical skills to the students.

10.2.2 Synthesis

- Synthesis needs to be emphasized as a process. It is further divided into five sub components:
  1. Conceptualization
  2. Diagrams/Sketches
  3. Selection, refinement
  4. Detailing
  5. Modelling
- Conceptualization as a skill can be improved by making it a part of a student's thinking process while doing various projects. Open ended questions in the assignments can deal with conceptualizing the various ways in which a problem can be solved.
- The skills of detailing and modelling need to be strengthened amongst students. Regular assignments based on re-design problems and practical based on modelling can help. The final outcome needs to have undergone a series of refinements. Emphasis needs to be laid on refining the output till it doesn't match industry standards.

10.2.3 Creativity

- Separate creativity sessions need to be held in dedicated time slots for students.
- Students can be divided into groups of three to five and different creative thinking approaches can be tried every time.
- Certain creative thinking exercises which should definitely be carried out are:
  - Ideation
  - Brainstorming
  - Synectics
  - Morphological charts
  - Lateral thinking
  - Affinity diagrams
  - Nominal group process
- A sample group can demonstrate how to carry out a creative thinking exercise to the entire class with the help of the faculty.
- Faculty can moderate these exercises while they are being carried out in groups in the class.
- These exercises help generate innovative ideas, new concepts and various approaches to solve a problem.

10 TEAM WORK AND COORDINATION

10.1 Introduction and basic breakup

In the current framework there is no provision for this section. It is mandatory for most of the engineers to work in teams in the industry. The teams are cross functional, interdisciplinary or having similarly skilled people, but they are always present in real life. There is hardly any time while studying when an engineer gets exposed to working in different types of teams and co-ordinating with his/her team members. In the industry, an engineer mostly is either a part of or heading an

interdisciplinary team and he/she has to coordinate with them constantly. Active steps need to be taken in this direction and dedicated activities need to be allocated to improve the situation. A good engineer needs to be a good team member as well as a good team leader [15]. This section has been divided into 3 major sub-components:
1. Interdisciplinary activities
2. Co-curricular activities
3. Industry collaborative activities

10.2 Guidelines

10.2.1 Interdisciplinary activities

- Engineers never work in isolation in the industry. They are always engaged in working with interdisciplinary teams. A similar environment needs to be simulated at college level. Having students work in an interdisciplinary team on a project is a first step towards achieving this.
- Electives from other branches need to be open to students as minor courses from third semester onwards. The students from other branches should attend these electives along with the students for whom this is a major subject.
- Visit to different engineering departments in the institute should be conducted for students so that they are aware of the various disciplines.
- Interdisciplinary group work can be given in the form of assignment, problem solving activity or a design activity. Interdisciplinary student teams can work together. It will enhance their inter-disciplinary knowledge and their ability to work in an inter-disciplinary team.

10.2.2 Co-curricular activities

- They are a very integral part of an engineer's learning but have been completely ignored in the current framework. These activities enhance team work and interpersonal skills.
- Forming a club for each engineering department which organizes technical workshops, competitions and activities regularly for their department should be done.
- Student chapters of known technical organizations should be opened. These student chapters organize inter departmental challenges, workshops and other activities related to the field.
- Students should be encouraged to take part in technical festivals and group competitions. This promotes an exchange of knowledge across the domains amongst the students.
- Performing arts, literature and music clubs should be setup to enable students to work together even in a non-technical environment.

10.2.3 Industry collaborative activities

- There is a huge gap in the way engineers work in industry and the way they work in a college environment. To reduce this gap there needs to be activities in collaboration with the industry.
- A summer training program by industry professionals at the college or in the industry at the end of third semester should be the first step.
- Technical challenges in the form of competitions can be made open by the college and industry together for the students wherein the students need to work in collaboration with industry professionals and develop the project.
- Expert lectures by industry professionals and alumni who are currently in the industry should be organized at regular intervals to keep students updated with latest trends and technologies.
- Field visits to concerned industries can be carried out by various engineering departments to let the students observe first hand as to how things are and how they function in the industry.
- Demonstrations by industry professionals on latest technologies and machinery can be arranged for the students at the college. It would help if the colleges develop a memorandum of understanding with different industries to help them in the longer run.

11 PRESENTATION AND COMMUNICATION SKILLS

11.1 Introduction and basic breakup

In the current framework under use there is no provision for presentation and communication skills. It is extremely important for an engineer to be able to present and communicate his/her ideas, concepts

and solutions to team mates, seniors or clients. Being able to make good presentations and deliver them effectively is a necessity. All the effort put behind coming up with a solution or an idea to solve a problem fails if it is not communicated effectively. This section has been the weak point of engineers and it is high time to take measures to improve it. It has been divided into 4 major sub-components:
1. Language skills
2. Project management
3. Presentations and seminars
4. Group discussions

11.2 Guidelines

11.2.1 Language skills

- Language skills have been divided into two main parts:
    1. Spoken/oral language
    2. Written communication
- Spoken language can be heavily improved by moderated group discussions. Seminars on latest trends and technologies by students can help them improve their oral communication skills.
- Elocution and extempore speaking competitions can be held at regular intervals to promote students to improve their spoken skills.
- Written communication comprises of two main parts - technical and non-technical writing.
- Technical writing can be improved by having dedicated slots where in students are made to practice writing reports, letters, e-mail, manuals, instructions, notices and memos.
- Essay and composition writing also need to be practised by students in dedicated time slots. Essay and composition writing competitions can be held to promote students.

11.2.2 Project management

- Engineers handle multiple projects in the industry and hence making provision for them to learn this skill while studying engineering is definitely necessary.
- Leadership quality needs to be inculcated into the students. They should be able to take initiative and take a lead in their projects. This needs to be included as part of the process.
- Team building can be achieved through giving group assignments and group projects. Through these activities even the interpersonal skills will improve as one learns how to communicate with different people and work together.
- Promoting students to take part in extra-curricular activities will help them improve interpersonal skills. Groups of students should be encouraged to take part in technical festivals and competitions. These events help students to build good teams and work in cohesion.
- Contingency management needs to be part of the process where in a student has to also submit a contingency plan along with the basic plan for their major project.
- Case studies of some famous engineering projects which had relied on their contingency plans can be taken up.

11.2.3 Presentations and seminars

- Being able to make and deliver good presentations has become a necessity for an engineering professional. It can be to his/her clients, company management or juniors.
- Having a great presentation for their own projects during engineering can be a major step towards learning how to make and deliver good presentations.
- Also, seminars on latest trends and technologies by students can help them improve their presentations skills and enhance their knowledge about the topic.
- An industry expert should be called to judge the seminars along with the faculty.

11.2.4 Group discussions

- Group discussions should be made a regular part of class activity.
- They help improve spoken language skills, interpersonal skills and make lectures interactive.
- Also, most of the companies that come to the college for placement have group discussion as one of their rounds of selecting students.
- The following areas would be best learnt/solved through group discussions:

- Idea generation
- Brainstorming
- Oral/spoken language skills
- Developing interdisciplinary perspectives
- Problem anticipation
- Concept understanding
- Doubt solving
- Open ended questions
- Current trends in technology

12 VALUE SYSTEM AND ETHICS

12.1 Introduction and basic breakup

In the current framework under use there is no provision for a dedicated slot for value system and ethics section. An engineer needs to be aware of professional ethics and needs to abide by them to maintain his/her integrity in the industry. Many times there is a conflict between professional and personal ethics and one should be aware of how to deal with them. Being aware of and able to implement this skill successfully along with the above mentioned other five components helps make one a complete engineer. This section has been divided into two major sub-components:
1. Value system
2. Professional ethics

12.2 Guidelines

12.2.1 Value system

- Value system comprises of common morality (values in society), personal morality, associated moral code and moral dilemmas. It can be best taught through case studies.
- Many a time in industry there is a conflict between personal morality and professional ethics. An engineer needs to be aware of how to deal with it. A good understanding of personal morality and the moral dilemmas can be developed through role plays and scenarios [16].

12.2.2 Professional ethics

- The ethics that are related to one’s profession are professional ethics. They are different from personal ethics. A clear understanding of the ethical code of conduct related to one’s engineering discipline is needed so as to maintain the integrity of the profession.
- Professional ethics consists of code of conducts between an engineer and the organization, clients/customers, environment, society and ethical conflicts faced by an engineer in the industry. It can be best taught using case studies and role plays [16].
- Various approaches employed to deal with different professional ethics dilemmas [17]:
    - Cost-benefit approach
    - Act utilitarian approach
    - Rule utilitarian approach
    - Golden rule approach
    - Rights approach
    - Self-defeating approach
- These would be best taught by a hypothetical scenario generation and putting an individual in it to see how he/she deals with the problem using one of the above mentioned approaches. Giving real life examples of the above mentioned approaches being implemented would help.

13 SELF LEARNING ENVIRONMENT

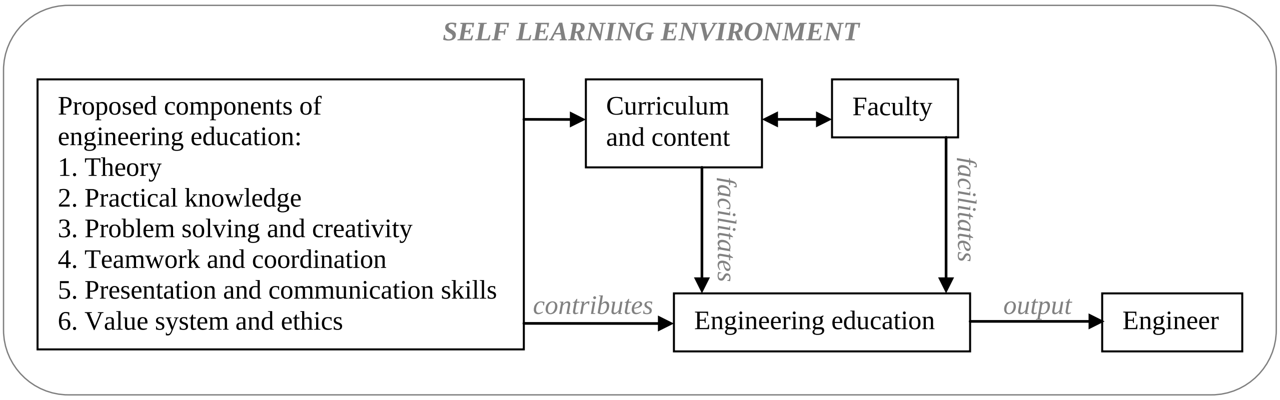

Figure 1. Proposed self-learning environment

14 CONCLUDING REMARKS

The study of the existing system for engineering education lead to interesting insights and combined with relevant user studies, referencing various publications and my own experience as an engineer led to the proposed new framework for engineering education. This paves the way for the creation of a self-learning environment in which the student will be less dependent on the faculty, the faculty will be a facilitator and the student will be better prepared for the industry. The new framework will help change the way curriculum and content is designed for engineering education and make way for the much needed and useful ICT based initiatives for the Indian engineering scenario.

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