Curriculum Design of Postgraduate Engineering Programs in India

N.J. Rao

1. Preamble

Curriculum is what you want your students to learn through the program and how you propose to facilitate this learning. Design of curriculum for any program should answer the following questions (Tylor 1949)

- What educational purpose should the program seek to attain?
- What educational experiences can be provided that are likely to attain these purposes?
- How can these educational experiences be effectively organized?
- How can we determine whether these purposes are being attained?

The educational purposes an engineering program in India seeks to attain are **program outcomes** chosen by the Department offering the program**.** These program outcomes are selected to meet the **Postgraduate Attributes** stated by the accreditation agency, National Board of Accreditation.

In view of the many ambiguities that still exist regarding engineering and its relation to science, technology and society it is necessary to state what engineering is before we design engineering programs. Here we state

"Engineering is finding and delivering effective solutions to real life technical problems, within the given material, technological, economic, social, legal and environmental constraints, through the application of available knowledge from mathematics, science, technology, engineering sciences and engineering practice."

The actual statement is not unique, and it may be treated as an operative definition. It may be rewritten in the spirit of the above statement

This document presents the characteristics of postgraduate education in India, and a framework, and a process for designing curriculum for a postgraduate program in any branch of engineering.

2. Postgraduate Education in Engineering

Postgraduate or Master's degree in Engineering indicates that the holder has mastered a program in a particular field sufficiently to pursue creative projects in that specialty. The Postgraduate degree (MTech or ME) is customarily awarded to an aspirant who achieves a level of academic accomplishment substantially beyond that required for the bachelor's degree. The Postgraduate program should consist of a coherent pattern of courses capped by a thesis or its equivalent in a creative project. Ideally, all postgraduate engineering programs should include an opportunity for the student to learn to present information in written and oral form to a variety of audiences. (Engineering Graduate Education and Research: http://www.nap.edu/catalog/585.html)

A thesis has been a requirement for the Postgraduate degree since its inception and has traditionally been a modest contribution to knowledge, certainly original to the student, and it may be original to the field. A significant, well-supervised master's thesis project clearly has value for the student and to the Department. The thesis (or creative design project) should be structured in such a way as to be a meaningful, creative experience for the student. While it need not be an original contribution to the knowledge of the field, it should be sufficiently difficult to challenge the student's best capabilities and should be original with the student, and should call upon knowledge and skill that lie substantially beyond the usual bachelor's level.

One of the purposes of a graduate program is to deepen a student's understanding of fundamental material. This, in turn, implies that there will be a greater emphasis on mathematics and science at the graduate level than at the undergraduate level, as well as an increasing degree of specialization. At the postgraduate level, students will be moving in the direction of the "cutting edge" of technology, where less material has been formally reduced to textbook form and much information is in the process of being discovered and organized. Since the latter process is the one called research, it is natural that graduate education is inextricably interwoven with research. At the master's level the involvement with research will typically be less than at the doctor's level. In the case of doctoral programs, the students are expected to work directly at the frontier of knowledge, and, in fact, to make original contributions of their own to the body of knowledge. The intimate involvement with research is what characteristically separates undergraduate and postgraduate education. Undergraduate students may be involved with research on occasion, master's students usually will be, and Ph.D. students always are.

The utilization of master's degree holders in industry differs from company to company. In many companies they are employed to do the same kind of work that a bachelor's degree engineer does. However, those with a master's degree can make a contribution sooner and with less additional training and experience. In other companies the view is that the master's degree is indeed a more specialized degree than the bachelor's, and the recipients are employed on more technically demanding tasks, similar to but perhaps less demanding than those that challenge a doctoral recipient.

Today's typical bachelor's program provides reasonable coverage in mathematics, basic sciences, engineering science, and engineering design. Humanities and social sciences are required but seldom are sufficient to prepare the student for an effective role as a "totally educated person."

After provision has been made in the undergraduate engineering curriculum for the components mentioned above, the remaining portion (about one year) is intended to provide for additional breadth, or sometimes depth, in the general disciplinary area of study. In the discipline of Electronics and Communication Engineering, for instance, this portion of the program is utilized to provide exposure, at a minimum level, to the several sub-disciplinary areas — Embedded Systems, VLSI, Computer Networks, Wireless Communication, Signal Processing — as well as to develop some rigor in problem solving, design, synthesis, and planning.

There is a dilemma in the practice of engineering by disciplines: on one hand, the problems presented are increasingly difficult, involving a much higher degree of sophistication—higher data rates, small packages, higher performances, energy conservation, dwindling material resources—thus requiring a more rigorous background and understanding of engineering sciences. On the other hand, these same problems are much more complex—hazardous wastes, environmental concerns, and economic and social aspects—so that their solutions require an interdisciplinary or multidisciplinary approach.

The traits of graduating engineers at postgraduate level including transferable skills in India are expressed as Graduate Attributes by National Board of Accreditation (NBA). The Graduate Attributes of PG programs identified by the National Board of Accreditation are

1. **Scholarship of Knowledge**: Acquire in-depth knowledge of specific discipline or professional area, including wider and global perspective, with an ability to discriminate, evaluate, analyze and synthesize existing and new knowledge, and integration of the same for enhancement of knowledge.
2. **Critical Thinking**: Analyze complex engineering problems critically, apply independent judgment for synthesizing information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context.
3. **Problem Solving**: Think laterally and originally, conceptualize and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors in the core areas of expertise.
4. **Research Skill**: Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyze and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.
5. **Usage of modern tools**: Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities with an understanding of the limitations.
6. **Collaborative and Multidisciplinary work**: Possess knowledge and understanding of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.
7. **Project Management and Finance**: Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economical and financial factors.
8. **Communication**: Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.
9. **Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
10. **Ethical Practices and Social Responsibility**: Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

11. **Independent and Reflective Learning**: Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

These Graduate Attributes may be compared with the Graduate Attributes of Undergraduate Engineering Programs as identified by NBA.

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

2. Stages of Curriculum Design

The four questions that need to be answered to design the curriculum of an engineering program are addressed through the stages (as per the guidelines of NBA 2013)

- Write Vision and Mission of the Department offering the program
- Identify the context of program
- Write Program Educational Objectives (PEO) consistent with the Mission and Vision of the Department
- Write the Program Outcomes (PO) to achieve (Post)Graduate Attributes (GA) as stated by NBA
- Prepare PO-GA Matrix and ensure that POs address all the GAs, and PO-PEO matrix to ensure POs facilitate realization of PEOs.
- Select the number of credits for the program and decide the distribution of Credits
- Identify the courses to meet the stated Program Outcomes
- Define the assessment process

4.1 Vision and Mission of the Department Offering the Program:

Vision Statement states where the faculty members "see" their Department in the future and/or where they want it to go.

Mission Statement states what you propose to "do" to get there

What's the benefit of having these statements? The provide focus, flow, and a foundation for decisions, in other words, thriving instead of surviving. When people within an institution/department align their efforts with an agreed-upon focus they save both time and frustration, and they make the institution/department achieve their academic objectives

These have to be created through brainstorming with several faculty members and have them reviewed by some of the important stakeholders. They should be as simple and brief as possible. It will make it easier to relate to them.

Sample Vision and Mission statement (Engineering College, Carnegie Mellon University)
Vision
To continue to be one of the world's leading engineering schools in both education and research and achieve greater recognition for our efforts in our chosen fields of endeavor. The world will look to us for future trends and innovations in education, research, and technology. The college will build on its traditions of innovation, problem solving, and interdisciplinary collaboration to meet the changing needs of society.
Mission

- To provide students with the fundamental knowledge, interdisciplinary problem solving skills, societal and business awareness, and confidence required to excel in their chosen professions and be leaders in a global environment.
- Be recognized as one of the elite engineering colleges through research, innovation in education, and the transfer of concepts and results to technology and engineering practice.

- To maintain a collegial, supportive, and diverse environment that encourages our students, faculty, and staff to achieve to the best of their abilities.

Some samples of mission and vision statements of educational institutions are given in the Annexure 1

4.2 Context of Engineering Programs

Today's engineer has to function in a world characterized by

- Information and communication technologies completely redefining how work is carried out and how business is organized and conducted.
- Large scale demographic changes taking place in every country with population increases in Asian and African countries and practically zero percent growth in advanced countries.
- Continuously changing global economic and political scenarios.
- Changing social and environmental scenarios where hunger, poverty, public health, sustainability, climate change, water resources and security constitute the great problems that face the humanity in general and particularly India at present.
- India is particularly characterized by large religious, linguistic and cultural diversity.

Engineers are at the centre of all developments, and also have to grapple with the consequences of all the technologies and products. Engineering programs are to be designed and conducted to train graduating engineers to work and contribute to the well being of the society, which is the supposed objective of engineering. However the programs have be designed and conducted taking the following factors into consideration.

a. As India plans to be a signatory to the Washington Accord to ensure global mobility of its graduate engineers, all engineering programs are to be designed and conducted to meet the Graduate Attributes as identified by National Board of Accreditation (NBA).
b. Students learn well when their learning is activity based. The number of credits of a program is to be chosen to ensure that students get enough time to be engaged in activities.
c. As all engineers have to conduct their activities in English in the global context, and English not being the native language for majority of Indians, the programs should provide for adequate training in oral and written communication in English.

The faculty responsible for the curriculum will prepare the context of the program in consultation with stakeholders and the vision and mission of the college/institution/University. (Sample of a context is given in the Annexure 2)

4.3. Program Educational Objectives: Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. They must be consistent with the mission of the institution and Department. Department faculty members must continuously work with stakeholders (local employers, industry and RD advisors, and the alumni) to review the PEOs and update them periodically. The number of PEOs should be manageable and small in number, say 5 ± 1, and should be achievable by the program.

A sample set of PEOs is presented in the following.

ME in Electronics Systems Engineering

PEO1. Graduates will specify, design, implement and test electronic products and systems for stated volumes of production for a given manufacturing context following the norms of green electronics.

PEO2. Graduates will uphold the values embodied in the institute's vision and mission.

PEO3. Graduates will be committed to the improvement of their communities while maintaining high professional ethical standards

PEO4. Graduates will pursue life-long learning as a means of enhancing the knowledge base and skills necessary to contribute to the improvement of their profession and community

4.4 Program Outcomes: Design of any program invariably starts with the debates on liberal versus utilitarian or conceptual versus industry ready education, debates that have been going on for centuries. The two views or sides are not mutually exclusive especially in engineering. The balance between these two dimensions can be stated, as normally done by Accreditation Agencies or Academies of Engineering in any country, and gets redefined after periodical reviews. Design of any program in engineering requires statements on what engineering is and who is considered to be a good engineer. The desirable traits of a good graduating engineer are decided by the requirements of the profession at the given time and are stated as Graduate Attributes by the Accreditation Agency. Engineering programs are to be designed and conducted to train graduating engineers to work and contribute to the well being of the society, which is the supposed objective of engineering.

Program Outcomes, as per NBA, are narrower statements that describe what the students are expected to know and be able to do upon the graduation. These relate to the knowledge, skills and behavior the students acquire through the program.

The Program Outcomes (PO) are specific to the program and should be consistent with the Graduate Attributes and facilitate the attainment of PEOs.

The number of POs should be 5 to 10, and should directly lead to the identification of core courses. All courses of the program should be designed to meet some or all of the program outcomes identified.

POs represent what the graduating engineer should be able to do. Hence each PO statement should start with one or more action verbs. The higher levels of learning (as per Bloom's cognitive levels) including Apply, Analyze, Evaluate and Create, should adequately be addressed. Bloom's cognitive levels and the associated action verbs are given in the Annexure 3. Here is a sample PO from Electrical Communication Engineering program.

"**Specify, design and test power supplies for electronic systems including battery management, and power amplifiers using currently available electronic components**."

The action verbs 'specify, design and test' belong to the higher levels of learning.

The POs should be written by a selected group of faculty members of a Department, and should be peer reviewed. They should also be reviewed by the industry experts. The final list of POs should be strongly communicated to all the faculty members of the Department and to all the stakeholders. A sample set of POs are presented in the following.

Program Outcomes of ME program in Electronics Systems Engineering

1. Specify electronic products in SOC and SOP form for communication/power management/ instrumentation application
2. Design, prototype and test electronic products and systems as per given functional and performance specifications and for stated volumes of production and a given manufacturing context.
3. Understand how the organizations manage their innovations and technologies to generate wealth.
4. Work in a team using common tools and environments, and meeting the industry standards and environmental norms to achieve project objectives
5. Recognize their professional and personal responsibility to the community
6. Pursue life-long learning as a means of enhancing the knowledge and skills necessary to contribute to the betterment of their profession and community

In order to ensure that all Program Educational Objectives and Graduate Attributes are addressed by the selected POs a PEO-PO matrix and a PO-GA matrix should be created. The PEO-PO matrix presents pictorially the adequacy of chosen POs, and can be used to iteratively improve the quality of POs. It is convenient to represent the level to which a PO meets a given PEO. Three levels may be identified as 1 – Slightly, 2 – Moderately and 3 – Substantially.

The **PEO-PO matrix** of the sample Electronics Systems Engineering program is

PEO	PO1	PO2	PO3	PO4	PO5	PO6
1	3	3				
2	2	2	2	3	3	3
3				1	3	
4						3

1: Slightly 2: Moderately 3: Substantially

The GA-PO relationships for ME in Electronics Systems Engineering are presented in the following

GA – PO Matrix

PO	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8	GA9	GA10	GA11
1	2	2	1	2	1	2	1	2		2	1
2	2	3	3	3	2	1		2	2		1
3						1	3	2		2	
4					2		2	2		2	2
5								1		2	1
6						1		2	3		1

1: Slightly 2: Moderately 3: Substantially

Creation of POs is the most important stage in curriculum design. When they are created for the first time by a Department it is necessary to debate all issues including the current practices, tools being used, how people learn, nature of the industry, abilities of students, employment history etc. It takes several iterations to prepare a set of good, differentiating and achievable Program Outcomes.

4.5. Credits of PG Programs in Engineering: Knowledge in all areas of Engineering and Science is exponentially growing. There is no way in which it is possible to include in curriculum what is considered to be adequate even at postgraduate level by any branch of engineering or any stream in a given branch. What can be attempted is facilitating students to learn well or learn meaningfully. Learning well is understood as acquiring knowledge and skills at higher cognitive levels, which include Apply, Analyze, Evaluate and Create. Such learning is ensured by making it heavily activity and practice oriented rather than lecture oriented. It is well established that for every one hour of classroom interaction, the student is required to spend two or more hours (Olin college officially identifies this as three hours) working alone or in a group. It is also acknowledged that

- A student at postgraduate level can put in a maximum of 60-65 hours, including classroom/laboratory hours, in a week
- With the current definition of credit (one hour of lecture, two/three hours of laboratory per week or one hour of tutorial per week over a semester), and the graduate students needing to spend more time on their own and in a group than undergraduate students, the total credit load for a postgraduate degree program in engineering can be about 60 to 75 credits.
- Programs around the country are operating anywhere from 64 to 100 credits.

Any credit load beyond 75 can result in reduction in the quality of learning.

4.6. Credit Distribution: An analysis of the graduate attributes indicates that subject areas in a PG program should include Humanities and Social Sciences, Basic Sciences, Engineering Sciences, Profession Subject Core, Professional Elective Core and Project/Thesis. A suggested credit distribution among various categories of courses is

S.No.	Subject Area	Range of Total *Credits (%)* *Min.*	*Max.*	Credits chosen
1	Humanities and Social Sciences *(HSS)*, including Management	5	10	5
2	Basic Sciences*(BS)*	5	10	4
3	Engineering Sciences *(ES)*	5	10	7
4	Professional Subjects-Core *(PSC)*, relevant to the chosen specialization/branch	35	45	27
5	Professional Subjects – Electives *(PSE)*, relevant to the chosen specialization/ branch	10	15	9
6	Project Work	20	30	18

	Range	80 120	70

Note: The indicated credit distribution is only an example. Each program can decide the credit distribution based on the technologies addressed and range of activities for which the program proposes to train its graduates. However, it should be noted even with minor changes in distribution the character of the program can be significantly altered.

4.7 Identification of Courses

Courses need to be identified to meet the stated Program Educational Objectives under different categories: Humanities and Social Sciences, Basic Sciences, Engineering Sciences, Professional Subject Core, Professional Subject Electives, Projects. In order to assure that all POs are adequately met through the courses and activities of the program it will be convenient to create a Course-PO matrix. While no course is designed to meet all the POs, all the courses and activities together have to meet all the POs adequately. A Course-PO matrix, created as an element of the course design presented elsewhere, can facilitate this process.

Each category of the courses is explored in the following for a sample PG program in Electronic Systems Engineering.

Humanities and Social Sciences courses should constitute 5 to 10% of total number of credits, which for 70 credits program works out to be 3 to 7 credits. These courses could include Written Communication, Technology and Society, Technology Management, International Trade etc.

Let us choose 5 credits for this category. It should also be noted that several Graduate Attributes can be directly met through these courses. The specific Graduate Attributes of concern include

1. **Project Management and Finance**: Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economical and financial factors.
2. **Communication**: Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.
3. **Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
4. **Ethical Practices and Social Responsibility**: Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

These courses need to be designed specifically to meet as many of these Graduate Attributes as possible. They may not be based on existing courses offered or readily available text-books. However, there is no dearth of resources on the Internet. The suggested courses include

Professional Skills for Electronics	1:0:1	2
ICE Technology for Development	2:0:1	3
Technology Management	3:0:0	
Project Management	3:0:0	
Technology and Society	3:0:0	

More courses can be added to this list**.**

Basic Sciences courses should constitute 5 to 10% of total number of credits, which for 70 credits program works out to be 3 to 7 credits. Keeping the needs for adequate number of professional core courses, it is proposed to have 3 credits for this category. The following basic science courses are proposed:

Mathematical Methods	3:0:0	3

Engineering Science courses should have 10 to15% weightage, which for 70 credit program works out to be 7 to 10 credits. Keeping the need for adequate number of professional core courses it is proposed to have 7 credits for this category. This category of courses includes Materials, Workshop, Drawing, Problem Solving through Programming, Basics of Electrical/Electronics/Mechanical/Aerospace Engineering, Computing and Instrumentation. One possible combination of courses under this category is given in the following. All the suggested courses can be considered as compulsory to all branches.

Electronic Systems	2:0:2	4
Computational Engineering	2:0:1	3

Professional Subject Core Courses: The number of credits for Professional Subject Core is proposed to be 27.

Analog and Mixed Signal Circuits	3:0:1	4
Design of Power Supplies	3:0:1	4
Design of Digital Systems	2:0:1	3
Embedded Systems	2:0:1	3
Design of ASICs	2:0:1	3
Electromagnetic Compatibility	3:0:0	3
Packaging of Electronic Systems	3:0:1	4
Design of Electronic Products and Systems	2:0:1	3

Projects: The weightage for this category of activity is 8 to 10%. Keeping the Professional Core requirements in consideration it is proposed that the number of credits for this activity be 19 credits.

MTech Project/Thesis	0:0:15	**18**

(The final year project is spread over 3rd and 4th Semesters with 3 Credits allotted to 3rd Semester and the remaining 12 credits to the 4th Semester)

There will be mini projects in even semesters during the first three years. These will provide opportunities to experience different streams in a discipline. These mini projects can be concerned with explorations, problem identification, problem formulation, conducting surveys, simulation, design of software or hardware systems, building prototypes

Mini project 1 (Second Semester) 0:0:3

Professional Electives: The weightage for this category of activity is 10 to 15%. Keeping the Professional Core requirements in consideration it is proposed that the number of credits for Professional Electives be 9 credits, amounting to three courses. A Department can offer a large number of electives depending on specializations of its faculty. These courses are designed to enhance the placement opportunities of students.

4.8. Assessment

Assessment is defined as a measure of performance. Evaluation is an interpretation of assessment. Educational assessment is the process of documenting, usually in measurable terms, knowledge, skills, attitudes and beliefs. Assessment is a mechanism for providing instructors with data for improving their teaching methods and for guiding and motivating students to be actively involved in their own learning. As such, assessment provides important feedback to both instructors and students. Assessment gives us essential information about what our students are learning and about the extent to which we are meeting our teaching goals. But the true power of assessment comes in using it to give feedback *to students*. Improving the quality of learning in a course involves not just determining to what extent students have mastered course content *at the end of the course*; improving the quality of learning also involves determining to what extent students are mastering content *throughout the course*. Thus in addition to providing the instructors with valuable information about our students' learning, assessment should assist the students in diagnosing *their own* learning. That is, assessment should help students "become more effective, self-assessing, self-directed learners." (Angelo and Cross, 1993)

There is considerable evidence showing that **assessment drives student learning**. More than anything else, our assessment tools tell students what we consider to be important. They will learn what we guide them to learn through our assessments. Traditional testing methods have been limited measures of student learning, and equally important, of limited value for guiding student learning. These methods are often inconsistent with the increasing emphasis being placed on the ability of students to think analytically, to understand and communicate at both detailed and "big picture" levels, and to acquire life-long skills that permit continuous adaptation to workplaces that are in constant flux. Moreover, because assessment is in many respects the glue that links the components of a course - its content, instructional methods, and skills development - changes in the structure of a course require coordinated changes in assessment.

The quality of learning in a course can be measured by the quality of assessment instruments used. Metrics to measure the quality of assessment can be defined in terms of distribution, difficulty level and nature of items (questions) among the six cognitive levels of Bloom. The nature of assessments and wightages given to sessionals and finals are mostly decided at the Institution or University level. However, the instructor can have some freedom at the levels of their courses in an autonomous institution.

Performance in each course of study is normally evaluated based on (i) continuous internal assessment throughout the semester and (ii) final examination at the end of the semester. The assessment pattern suggested below is only a sample. The distribution of marks between Sessionals and Finals vary from 50:50 to 20:80 in India.

- Theory Courses (Courses with 3:0:0 or 3:1:0) will be assessed as per

  Finals: 50

  Finals consists of one written examination

  Sessionals: 50

  Sessionals must include at least two mid-semester tests
- Courses with Laboratory (Courses with 3:0:1) will be assessed as per

  Finals: 50

  Finals consists of a written examination (40) and laboratory examination (10)

  Sessionals: 50

  Sessionals must give a weightage of 15 marks to the Laboratory
- Courses with Laboratory (Courses with 2:0:1 like electives with laboratories) will be assessed as per

  Finals: 50

  Finals consists of a written examination (30) and Laboratory (20)

  Sessionals: 50

  Sessionals must give a weightage of 30 marks to the Laboratory, and also include two mid-semester tests each carrying
- Courses with two laboratory sessions per week (Courses 1:0:2 Course) will be assessed as per

  Finals: 50.

  Sessionals: 50 (At least one written test)
- Laboratory courses (Courses with 0:0:1) will be assessed as per

  Finals: 50

  Finals consist of laboratory/workshop exercises.

  Sessionals: 50
- Project work may be allotted to a single student or to a group of students not exceeding 2 per group. Each Department will define its own rubrics for evaluation of mini projects and projects.

References

1. Tylor R.W., Basic Principles of Curriculum and Instruction, The University of Chicago Press, 1949
2. Accreditation Manual for PG Engineering Programs (TIER-I), National Board of Accreditation, India, 2013.

3. Purdue University: http://www.extension.purdue.edu/extmedia/EC/EC-720.pdf
4. Angelo, T. A. & Cross, K. P., Classroom assessment techniques: A handbook for college teachers, San Francisco, Jossey-Bass, 1993.

Annexure 1: Samples of Mission and Vision Statements

Sample 1

Vision

To be one of the nation's premier engineering colleges by achieving the highest order of excellence in teaching and research. We will be the preferred choice of students seeking engineering

Mission

- To impart quality technical education that meets the needs of present and emerging technological world.
- To strive for student achievement and success, preparing them for life and leadership
- To provide a scholarly and vibrant learning environment that enables staff and students achieve personal and professional growth.
- To contribute to advancement of knowledge in both fundamental and applied areas of engineering & technology
- To forge mutually beneficial relationships with governmental entities, industry, society and the alumni

Sample 2

Vision

To empower young generations for substantial contribution to economical, technological and social progress of the society

Mission

To be a Globally-Socially conscious institute of research and innovation with excellence in professional education to take up the challenges of change for benefit of the society

Sample 3

Vision

The Institute is committed to responsibly serve the global community and local community in particular through offering its students an academic experience of meaningful and active learning and enable them to create effective solutions to real world technical problems.

Mission

To provide its students education in engineering that combines rigorous academic study and the excitement of designing engineering systems, and develop each member of its community the ability and passion to work wisely, creatively and effectively for improving the quality of life.

Sample 4

Vision

- To Produce World class Engineers for converting global challenges into Opportunities through "Value Embedded Quality Technical Education".
- To develop this College as an Academy of Higher Learning in the field of Engineering & Technology.

Mission

- To Impart Technical Education through effective teaching-learning process,
- To nurture creativity and critical thinking in applying engineering skills to face the fast growing globalization,
- To Develop Holistic Personality of the learners,
- To make this Institute as a Lead Centre of Research.

Sample 5

Vision

The San Francisco Bay Area is a world center for science and technology. It needs large numbers of well-educated scientists and engineers. The College is committed to serving this need by recruiting talented students, providing them with high-quality and up-to-date curricula, and fostering an effective teaching/learning environment. The College will be a leading provider of first-rate scientists and engineers in the Bay Area.

The College is committed to offering students an academic experience of "thinking, learning, and doing." The best way to provide this experience is through involving students in research and the solution of real world problems. Thus, teaching and research are mutually supportive and one cannot excel without the other. The College encourages the faculty to carry on research which involves students and which serves the science and engineering community. The College will be competitive in science and engineering research and teaching at the national level.

The College is committed to full participation in the community through service. This service applies the knowledge and experience of its faculty, staff and students to the solution of problems facing the University, industry, government, or civic organizations. The College will expand its already strong cooperative relationship with various local and national organizations, especially in areas related to K-12 science and math education.

The College is committed to serve a student population that reflects the diversity of the region and includes many international students. The College supports a number of programs designed to encourage and support all students to pursue careers in science and engineering. The College will support and retain a diverse group of faculty, staff, and students, both domestic and international.

Mission

The mission of the College of Science and Engineering at San Francisco State University is to provide an encouraging environment to develop the intellectual capacity, critical thinking, creativity, and problem solving ability of its students so that they may become honorable, contributing, and forward-thinking members of the science and engineering community of the San Francisco Bay Area and beyond; to foster a conducive environment for scholarly and creative activities so that new knowledge or solutions to problems are discovered or created; and to provide science education to all students in the University so that they may be equipped to succeed in the modern world.

Sample 6 (Massachusetts Institute of Technology)

Vision (as expressed in 1991 by Charles Marstiller Vest, Fifteenth President)

MIT will be a preeminent wellspring of scientific knowledge and technological innovation. MIT will foster the pursuits of individual scholars, whose work so often leads to truly fundamental discoveries. We will be known for our ability to establish new and effective methods for analyzing complex and pervasive issues facing the nation and the world. In an invigorated partnership with industry, the government, and other educational institutions, we will contribute profoundly to their solution. MIT will be known for educating engineers who combine the spirit of innovation and invention with a passion for the highest quality and efficiency in design and production.

MIT will better reflect in our students, faculty, and our staff the changing face of America. We will find ways to instill the excitement and romance of science and mathematics in new generations of young people. MIT will spearhead efforts to rekindle our nation's belief in the importance of scientific research and education. We will have found renewed commitment to the deepest values of the academy. MIT will stand for integrity in all that it does. MIT will serve our nation well, but also will be of and for the greater world community.

Above all, the Massachusetts Institute of Technology will be a place to which the brightest young men and women will come for their education. They will be able to attend MIT regardless of their financial circumstances. They will be taught and counseled by dedicated teachers who themselves define the leading edge of human knowledge and invention. Their education will be robust: deep in scientific content, yet providing the flexibility and learning skills to serve them well in ever changing and expanding circumstances. They will be attuned to the complexities of their world, a world that they will help to change. Through that wonderful blend of undergraduate education, graduate education, research and creative activity that is MIT, our students will be enriched and they, in turn, will enrich the Institute.

Mission

To advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century.

The Institute is committed to generating, disseminating, and preserving knowledge, and to working with others to bring this knowledge to bear on the world's great challenges. MIT is dedicated to providing its students with an education that combines rigorous academic study and the excitement of discovery with the support and intellectual stimulation of a diverse campus community. We seek to develop in each member of the MIT community the ability and passion to work wisely, creatively, and effectively for the betterment of humankind.

Annexure 2: Sample "Context of the Program"

ME in Electronics Systems Engineering

1. Information, communication and electronics technologies are completely redefining how work is carried out and how business is organized and conducted.
2. Large scale demographic changes taking place in every country with population increases in Asian and African countries and practically zero percent growth in advanced countries.
3. Continuously changing global economic and political scenarios.
4. Changing social and environmental scenarios where hunger, poverty, public health, sustainability, climate change, water resources and security constitute the great problems that face the humanity in general and particularly India at present.
5. India is particularly characterized by large religious, linguistic and cultural diversity.
6. Electronics industry is predominantly driven by technology.
7. Cost/performance ratios of electronic products and systems continuously decrease.
8. A large percentage of electronic products are portable and Internet enabled.
9. Electronic product life cycles are becoming shorter.
10. There is urgent need to reduce power consumption at every level
11. The performance of electronic systems is at present limited by Electronic packaging technologies.
12. Electronic industry is organized horizontally worldwide.
13. Recognizing the centrality of electronic industry Government of India has launched ESDM (Electronics Systems Design and Manufacturing) initiative.

Annexure 3: Cognitive Levels and Action Verbs

Cognitive learning is demonstrated by knowledge recall and the intellectual skills: comprehending information, organizing ideas, analyzing and synthesizing data, applying knowledge, choosing among alternatives in problem solving, and evaluating ideas or actions. The cognitive domain of the acquisition and use of knowledge is predominant in the majority of courses. Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order, which is classified as creation. The six progressive stages of cognitive thinking, as accepted at present, and called as Boom's taxonomy o cognition, are

- Remember
- Understand
- Apply
- Analyze
- Evaluate
- Create

Initial work of Bloom was followed up with research that resulted in a list of Action Verbs representing intellectual activity on each respective level of the cognitive domain.

Action Verbs associated with Bloom's cognitive levels

Remember

- Recognize/Identify
- Recall/Retrieve: List, mention, state, draw, label, define, name, describe, prove a theorem tell, show, label, collect, examine, tabulate, quote, who, when, where, etc.

Understand

- Interpret: Translate, paraphrase, represent, describe, express, extend and clarify
- Exemplify: Illustrate and instantiate
- Classify: Categorize and subsume
- Summarize: Generalize and abstract
- Infer: Extrapolate, interpolate, predict, conclude
- Compare: Contrast, match, map, distinguish and differentiate
- Explain: Illustrate, construct a model, confirm, state, write down, associate and discuss

Apply

- Execute: Determine, calculate, compute, estimate solve, use, draw, and carry out (a procedure in known situation)
- Implementing: Determine, calculate, compute, estimate solve, use draw, and carry out (a procedure in unfamiliar situation)

Analyze

- Differentiate: discriminate, select, focus and distinguish (between accurate and inaccurate, cause and effect, consistent and inconsistent, dominant and subordinate, essential and inessential, facts and conclusions, facts and hypotheses, facts and inferences, facts and opinions, facts and value statements, plausible and implausible, possible and impossible, relevant and irrelevant, summaries and conclusions, supportive and contradictory, valid and invalid, verifiable and unverifiable, warranted and unwarranted)

- Organize: Identify (adequacy, assumptions, attributes, biases, causes, central issues, completeness, concepts, consequences, contradictions, criteria, defects, distortions, effects, elements, errors, exceptions, fallacies, inconsistencies, inferences, limitations, main ideas, nature of evidence, organization, plausibility, problems, procedures, reasoning, relationships, relevance, stereotypes, trends, validity, variables), structure, integrate, find coherence, outline and parse.
- Attribute: Deconstruct and ascertain (Assumptions, attitudes, biases, conditions, characteristics, motives, organization, points of view, purposes, qualities, relationships)

Evaluate

- Check/test (Accuracy, adequacy, appropriateness, clarity, cohesiveness, completeness, consistency, correctness, credibility, organization, reasonableness, reasoning, relationships, reliability, significance, usefulness, validity, values, worth), detect, monitor and coordinate.
- Critique/judge (Criteria, standards, and procedures)

Create

- Generate alternatives and hypotheses
- Plan/design
- Produce/construct