Developing suitable pedagogical methods for various classes, intellectual calibres and research in e-learning

National Mission Project on Education through ICT
MHRD, Government of India

Project Brief

For

Course Reviewers and Course Developers

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Project Objective: Redesigning Engineering Education for the 21st Century

Summary

This project is an experiment to systematically design and develop learner-centric curricula, suitable for outcome-based learning, for 4 year degree programmes in major engineering disciplines with the help of a large number of motivated, trained and experienced faculty members drawn from a diverse range of institutions across the nation. The design uses innovative pedagogic principles to take care of many of the problems inherent in the present day higher technical education system.

This is **NOT**, **yet another attempt to develop content.**

Section 1 provides an overview of the project explaining the spirit and expectations from the course development team.
Section 2 provides the necessary Pedagogic Background to enable faculty team to develop/review the courses in the same spirit in which the project was conceived.
Section 3 deals with the specific issues the reviewers are expected to comment on.

Annexure 1 is a must read for both the developers and the reviewers to ensure that selected objectives are written using appropriate action verbs.
Annexure 2 provides details of Affective and Psychomotor domains of learning which deal with attitudes/ behaviour and skills requiring physical activities
Annexure 3 shows course objectives vs. learning outcome matrix.

The challenge

1. **Can we develop curriculum documents for different engineering degree programmes which specify, in clear unambiguous terms, what knowledge skills and attitudes the students must possess to qualify as graduate engineers in the 21st century?**
2. **Can we make education learner centric, so that individual differences amongst learners are taken care of?**
3. **Can we ensure that our students become efficient and effective lifelong learners?**

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1. Overview

1.1The Problem

Education in India and also in most parts of the world is teacher-centric. Teachers decide what to teach and how to teach. A syllabus is usually no more than a list of topics, allowing different interpretation by different people. Students rarely have any idea about what is expected of them, until the course is over, more often than not until they see the examination paper. Most courses are taught to *familiarize / expose* students with the topics mentioned in the syllabus. The emphasis is mostly on the ability to recall information, explain and at best apply some of the concepts learnt in the class. Development of analysis, synthesis and evaluation skills rarely get the priority that they deserve. Encouraging active learning, teaching self learning skills, effective communication skills, working in interdisciplinary groups are not practiced as a matter of policy.

Very few courses attempt to cultivate the essential knowledge and skills required by all graduate engineers of the 21st century. Examples of such skills include the ability to solve complex engineering problems, conceptualize engineering models, become lifelong learners, communicate effectively etc.

Most classes today have large number of students making it impossible to give individual attention. Individual differences amongst learners such as the learning styles, motivation, intellectual calibres, and preparedness are large and yet we make no allowances for these in our teaching.

1.2 Approach to solutions

This project is intended to address these problems through the following measures:

1.2.1 Sensitize a large number of faculty members to the problems and encourage them to find pragmatic solutions by participating in this national project.

1.2.2 Conduct motivation and training workshops in modern pedagogic principles for the interested faculty members.

1.2.3 Systematically design and develop learner-centric curriculum, suitable for outcome-based learning, for a representative range of 4 year degree programmes in major engineering disciplines, with the help of a large number of motivated, trained and experienced faculty members drawn from a diverse range of institutions across the nation.

1.2.4 Develop and use appropriate ICT tools to train faculty members, to design, develop, monitor and review curricula, to manage the project and to eventually conduct field trials through wider participation of students, teachers and industry professionals.

1.2.5 Write curricula not as a list vaguely defined topics but in terms of measurable Specific Instructional Objectives.

1.2.6 Divide every course into suitable number of modules and each module into suitable number of units.

1.2.7 Write Specific Instructional Objectives at Course level (5-8 objectives/course), Module level (5-8 objectives/module) and at Unit level (2-3 objectives/unit)

1.2.8 Include references to appropriate learning material for all instructional objectives (texts, websites, journals, videos etc.) as a part of learning strategy suggestions.

1.2.9 Include adequate number of nontrivial practice problems, assignments etc matching every instructional objective, to allow students test their learning success.

1.2.10 Facilitate peer to peer interaction, peer to mentor interaction, encourage collaborative group learning, self-paced learning, life-long learning, development of literature search skills, communication skills, problem solving skills, development of concern for societal issues through appropriate choice of instructional objectives, by suggesting appropriate learning strategies, and through provision of appropriate ICT tools during the operational phase.

1.2.11 Make the document available to all concerned.

1.2.12 The courses being developed are not meant to be prescriptive for anyone, nor do they represent the views of the institution/ department to which the development team belongs. They may, however be adopted/ adapted by those institutions who believe that their *Mission*, *Vision* and *PEOs* are close enough to the stated *Mission*, *Vision* and the *PEO*s. They could act as guidelines for others who wish to develop their own curricula

1.3 Guidelines provided to curriculum team

1.3.1 Decide on what generic knowledge, skills and attitudes and what domain specific knowledge and skills all students must possess when they graduate as engineers.

1.3.2 Assume that all graduates must possess the same generic knowledge, skills and attitudes listed under the head “Graduate Attributes/ Learning Outcomes” shown in section 2.2.3

1.3.3 The combined set of requirements is usually reflected in the Programmed Educational Objectives (PEO) of a department offering a UG programme in engineering. The PEO reflects the *Mission* and the *Vision* of the institution, a set of specified generic learning outcomes, a set of domain specific knowledge and skills and the strengths, weaknesses and views of the concerned department

1.3.4 The nature of domain specific knowledge and skills, expected from the students, even for the same discipline, may vary from one institution to another depending on the *Mission* and *Vision* of each institution and also on the strengths, weaknesses and views of departments. Thus two institutions offering a bachelor's programme, for example, in civil engineering, may not teach the same set of courses or even teach a given course in the same way. Every course designed in this project must be viewed against the (actual or assumed) stated PEO and also the (actual or assumed) stated *Vision* and *Mission* statements.

1.3.5 To satisfy the diverse requirements of the PEO, every degree programme needs to identify set of compulsory courses, with clear justification for each course.

1.3.6 Each course needs to be designed to address as many of the "learning outcomes" as possible in addition to addressing the domain specific knowledge and skills. It is understood that all courses are not equally suited to address all "learning outcomes". However, through the combination of all compulsory courses, it should be possible to address all "learning outcomes" adequately.

1.3.7 All courses should be designed to emphasize more on the development of application, analysis, synthesis and evaluation skills than on the ability to recall information and explain. Course design should ensure that they are not primarily information oriented.

1.4 Suggested curriculum design procedure

1) The Curriculum design task is expected to be taken up by a team of 2-3 faculty members. Only those who have taught a particular course for at least 2 years are entitled to take up the work.
2) A total of 121 courses spread over around 12 disciplines have been taken up in the pilot phase of the project.
3) The total design and development work for a course may take around 800 hrs. Only a part of the work (3/8 of the total) for each course is expected to be completed and reviewed during the pilot phase (ending on 31st March, 2010.)
4) Every course should ideally begin by stating the *Vision* and the *Mission* of the institution and the PEO of the department for which the course has validity. Course development team leaders may assume their own *Vision* and *Mission* statements and PEO, in case these are not available. It is immaterial whether these are real or assumed as the validity of the course design is judged only against the stated PEO which in turn depends partially on the *Vision* and *Mission* statements.
5) Typically a course is expected to have no more than 5-8 groups of objectives, 5-10 modules, and total of 40 units spread over the modules. A typical module may have 5-8 objectives and a unit may have 2-3 objectives. Learning time for all the objectives of a

unit should not require more than 2-3 hrs (including class hour, self study, solving assignments etc) of work for an average ability student.

6) Sufficient number of original, non-trivial practice problems, assignments need to be developed and included in the curriculum document to allow students the opportunity to test their learning. Solutions to all problems must be included. (Answers and solutions will not be made available to the students along with the problems/ assignments during the field trial and operational phase of the project).

7) All problems/ assignments etc. are to be designed to test only the corresponding stated specific instructional objectives. All problems must be written using action verbs listed in Appendix 1.

8) On an average, there should be 2-3 unit level problems/ assignments (total of around 100 unit level problems for a full course of 40 units), 2 module level problems requiring demonstration of mastery of all or most units of the corresponding module (total of around 14 module level problems/ assignments) and 3 course level problems for the full course.

9) Since one of the major objectives of this project is to develop a document for all courses in such a way as to allow the students the opportunity to learn on their own, it is helpful to have a short summary of all units listing the main concerns of the unit. This is NOT meant to be full lesson note, the initiative to read and write their own lesson notes must remain with the students. Unit summary should ideally also include comments on the importance/ application of that unit where relevant. Typical length of a unit summary is around two pages. The unit summaries of a given module could be combined, interrelated and written as the Module Summary, if desired.

1.5 Activity list for course developers including an estimation of time requirement

Activity	***Approx length (pages)***	***Approx length (words)***	***Approx time (hrs)***	***Comments***
Curriculum Design Activity				
1.Institute Mission & Vision	*0.5*	*250*	*2*	*Common for all depts.*
2.Programme Educational Objective of depts.	*0.25*	*125*	*4*	*Common for all courses of same prog*
3.List of courses with justification	*1*	*500*	*4*	*Typically 12-15courses*
4.Course Objectives	*0.25 - 0.5*	*125 - 250*	*4*	
5.Course Overview	*0.5*	*250*	*3*	

6.Module Objectives (8 modules)	*0.25(x7)*	*125(x7)*	*3(x7)=21*	*Assumption: 1Mod = 5 to 6 units*
7.Module Overview	*0.25 - 0.5*	*125 - 250*	*2(x7)=14*	
8.Unit Objectives	*0.25(X40)*	*125(X40)*	*2(x40)=80*	*1 course= 40 units*
9.Units Summary	*2*	*1000*	*3(X40)=120*	*may include diagrams*
10.Learning Obj Vs Learng Outcome Matrix	*4*	*N/A*	*12*	*Format to be provided later*
11.Core courses Vs Learng Outcome Matrix	*1*	*N/A*	*8*	*Format to be provided later*
			Subtotal =272	

Curriculum Development Activity

12.Problems /assignment (unit level)+ solns	*N/A*	*N/A*	*4(X100)=400*	*Total 100 problems @4hrs/prob+solns (for a course of 40 units)*
13.Problems /assignment (mod level)+ solns	*N/A*	*N/A*	*4 (X2X7)=56*	*(4hrs /prob) X (2 probs /mod) x 8mod*
14.Learning strategy at module level	*3 to 5*	*N/A*	*8X7=56*	*Strategy to be suggested for all units*
15.Problems/assignments (course level)+solutions	*N/A*	*N/A*	*4X2=8*	*(4hrs/ problems) x (2 problems+ solutions) / course*
16.Suggected assessment tools			*4*	
17.Suggested evaluation tools			*4*	
			Subtotal=528	
			Total=800	

Deliverables by 23rd Dec,2009 Note 1

Item	***Time Estimate*** *Hours*
Items 1 to 7- complete	*52*
Item 8 for first 22 units	*44*
Item 9 for first 22 units	*66*
Item 10 for 22 units / 3 modules	*6*
Item 12 -25 problems / assignments +solutions	*100*
Item 13 for 2 modules	*16*
Item14 for 2 modules	*16*
	Subtotal = 300 hrs

Note 1: Extended till 23rd March, 2010 for completion, including incorporation of review comments

2. Pedagogic Background Material

2.1 Writing Course Objectives

Section Summary: *In a curriculum document, a course should be written in terms of Specific Instructional Objectives using appropriate Action Verbs (shown in appendix 1) rather than as a list of topics.*

- Most technical institutions usually have a curriculum document that lists a set of courses, grouped under various heads that a student must take, to qualify as a Graduate Engineer. Some of these courses are "Compulsory", others are "Electives". Usually the course description is written as ***a list of topics*** (degree of detailing varies), at times, showing the approximate time needed to cover a topic/ a set of topics and also a list of suggested texts, reference books for the course. Assessment plans (marks distribution for tests and examinations) are also included in the curriculum document.

EXAMPLE:

Soil Mechanics [Core; Laboratory Course]

- ***A typical Course Overview, written as a list of topics***

Origin of soil, *identification and classification of soils,* phase relationship, effective stress principle, permeability, compressibility, shear strength, compaction, total and effective stress paths. Experiments; visual classification: water content determination: *Atterberg limits; grain size* analysis; specific gravity test, consolidation test; compaction test.

A typical detailed syllabus (partial): Identification and classification of soils
Grain size distribution of soils: Size definition, mechanical analysis and hydrometer analysis-co-efficient of uniformity and coefficient of curvature wall graded, uniformly graded and gap graded soil.

- ***Part of the same course written in terms of Instructional Objectives***

The same course can be rewritten in a different way, as a series of **Specific Instructional Objectives** using **"Action Verbs" which are demonstrable and clearly measurable (shown in green type face)**

Identification and classification of soils

Objectives: **On completion, the student will be able to:**

1. Visually classify soils
2. Conduct a sieve analysis and hydrometer test: from the results
   - draw a grain size distribution curve
   - compute the coefficient of uniformity & curvature
   - determine the content of sand, silt, clay.
   - designate the sample in terms of the grain size.

***Atterberg limits; grain size* analysis**

Conduct Atterberg's Limits Test

2. Define the different states of soil and their relationship to the limits, i.e. liquid limit, plastic limit and shrinkage limit.
3. Estimate the limits of different soils by visual inspection

- ***Another course (Theory) written in terms of Instructional Objectives***

On Completion the student should be able to:

- explain the process of cold working.
- select temperatures for cold working process of steel and other metals.
- state engineering examples of cold working processes.
- identify and state the effect of cold working on the properties of steel and other metallic substance.
- identify the effect of cold working on the crystalline structure.
- state when cold-working process is preferred to hot-working process.

Advantages of Instructional Objectives

- There are many obvious advantages in writing a course in terms of **instructional objectives**

- Everyone - the instructors, the examiners (if different), the students, the employers, the departments and the parents- unambiguously understand what the **students should be able to DO on successful completion of the course.**
- Since the objectives are clearly defined, **instructors** can plan teaching in a focused way.
- Even if some **students** miss a lesson or for whatever reason, do not understand the instructor properly, they can try to learn on their own in a more focused way.
- Since only **Action Verbs** are used and they are measurable, assessment of student achievement is **more objective** and less erroneous.

- Adds **transparency to the curriculum**, increases accountability and not being open to multiple interpretation, any need for change can be identified easily.

NOTE

There is no place for stating intended activities of the instructors. Examples are:

- I will teach/explain/tell/draw/sketch etc as none of these actions guarantee that the student will able to DO what they are supposed to do. Instructional objectives are statements of expected student performance. Different teaching/learning strategies may have to be adopted for different students.
- Verbs such as those listed below should not be used as they are neither demonstrable nor easily measurable:
- Appreciate, know, understand, feel, learn, grasp, and listen to.

Action verbs which may be used to write Instructional Objectives are shown in Appendix 1.

2.2 Selecting Appropriate Instructional Objectives

Section Summary: *Graduate engineers need to have proven abilities not only in **remembering** and **understanding** the essential knowledge and **applying** various concepts, principles and theories learnt in the university, but also in **analyzing** complex engineering problems, **synthesizing** appropriate solutions, **evaluating** various alternative approaches/ solutions/ products and processes. While designing a course for an engineering degree programme, it is essential to select Instructional Objectives with major emphasis on the higher level cognitive skills like the ability to analyze, synthesize and evaluate problems and solutions. If a course is designed where the instructional objectives mainly require a student to remember facts and figures, methodologies, conventions, trends, sequences etc and at best understand and apply some of the important concepts/ principles, then the course is more likely to be suited to a technician than an engineer. In this section, we first examine how to ensure that we have not selected too many lower level objectives.*

2.2.1. Taxonomies of Learning.

Historical Background

A group of college and university professors led by Benjamin S. Bloom published a handbook in 1956 called "Taxonomy of Educational Objectives –The classification of Educational Goals". Bloom's Taxonomy is used extensively for planning of teaching / learning activities

Domains of Learning

According to Bloom's Taxonomy, all learning can broadly be classified into one of the following three domains:

1. COGNITIVE DOMAIN : Involves mainly Thinking
2. PSYCHOMOTOR DOMAIN : Involves mainly Action
3. AFFECTIVE DOMAIN : Involves Feelings / Attitudes

Each domain has 5 -6 levels that are hierarchical in terms of complexity

Cognitive Domain is the domain most involved in higher learning. It has six levels.

Most difficult to master	6. Creation / Evaluation
	5. Synthesis
	4. Analysis
	3. Application
	2. Comprehension
Easiest to master	1. Knowledge

Bloom and his colleagues used the term "knowledge" not in the traditional way but to refer to those cognitive skills which only needed memorization. Brief explanation of each of these domains is given below.

Knowledge: The ability to recall information (Lowest Level)

Comprehension: The ability to grasp meaning of material.

Application: The ability to use a concept in a new situation.

Analysis: The ability to break down material into its component parts so that its organizational structure may be understood.

Synthesis: The ability to build a structure or pattern from diverse elements and/or put parts together to form a whole, with emphasis on creating a new meaning or structure.

Evaluation: The ability to make judgments about the value of ideas or materials (Highest Level)

Knowledge of terminologies, specific facts, conventions, trends and sequences, classifications and categories, various criteria, methodologies, principles and generalizations, theories and structures etc are considered essential before one can grasp the meaning of any new learning situation/ concept/ theory/ principle (Comprehension). It is clear that each level requires mastery of all the lower levels.

Details of the Psychomotor and the Affective Domain are given in Annexure 2

2.2.2 Specification Matrix: A simple tool to assist course design

Table 1 shows a Specification Matrix for a hypothetical course in Thermodynamics. There are 11 Modules, the first is the *Introduction* and the last is the *Entropy*. We assume that the first module *Introduction* has 3 objectives, 2 at **K**nowledge level and 1 at **C**omprehension level (shown in row 1) and the last module *Entropy* has 4 Instructional Objectives, 1 at **K**nowledge, 2 at **C**omprehension and 1 at **Ap**plication levels (row 11). For the remaining modules we have assumed different no. of instructional objectives at different levels and have shown these in the table. The course has a total of 107 objectives over the 11 modules. After normalization it is seen that the course has 29% Knowledge level, 32.7% Comprehension level and 38.3% Application level Instructional Objectives. The distribution of Instructional Objectives makes this course more suited to a diploma level programme than a degree level programme. The last column of the Matrix gives a rough indication to the weights allotted to the various modules. **This exercise helps us to see at a glance if a degree level engineering course is too heavily *Information Oriented (over emphasizing knowledge, comprehension and at best application level instructional objectives).***

It still does not provide us with enough guidance on how to <u>select appropriate</u> Instructional Objectives. For that we need to understand the concept of <u>Outcome-based Learning.</u>

	<u>Lowest</u>					**<u>Highest</u>**		
Levels of Learning →	**K**	**C**	**Ap**	**An**	**Syn**	**Ev**	**Total**	**%**
<u>Module List</u>	**<u>No. of Instructional Objectives at different levels for each Module</u>**							
1. Introduction	**2**	**1**	**-**	**-**	**-**	**-**	**3**	
2. Temperature	**3**	**3**	**4**	**-**	**-**	**-**	**10**	**9.3**
3. Heat	**4**	**5**	**4**	**-**	**-**	**-**	**13**	**12**
4. Abcdef	**1**	**1**	**4**	**-**	**-**	**-**	**6**	
5. xxxxxxxxxxxxxxx.	**2**	**1**	**2**	**-**	**-**	**-**	**5**	
6. bacbacbacbacbac	**1**	**2**	**-**	**-**	**-**	**-**	**3**	
7. Laws of Thermodynamics	**2**	**3**	**1**	**-**	**-**	**-**	**6**	
8. Xxyyxxyy	**5**	**5**	**7**	**-**	**-**	**-**	**17**	**15.9**
9. Xyxyxyxy	**6**	**6**	**9**	**-**	**-**	**-**	**21**	**19.6**
10. Xzxzxzxz	**4**	**6**	**9**	**-**	**-**	**-**	**19**	**17.81**
11. Entropy	**1**	**2**	**1**	**-**	**-**	**-**	**4**	
Total	**31**	**35**	**41**	**-**	**-**	**-**	**107**	
Percentage 100%	**29%**	**32.7%**	**38.3%**	**-**		**-**	**-**	

Table 1 Specification Matrix of a hypothetical course on Thermodynamics

2.2.3 Outcome-based Learning.

In an agreement signed in Washington in 1989, academicians of several countries listed a set of *Graduate Attributes* which engineers, cutting across disciplines, must demonstrate to qualify as Graduate Engineers. **Termed *Learning Outcomes***, these are **generic skills and attitudes, considered as essential requirements of 21st century graduate engineers** and must be learnt by all engineers **over and above the domain knowledge in their chosen disciplines.** The *Graduate Attributes* as specified in the Washington Accord in 1969 and subsequently endorsed by many more countries in 2007 are listed below.

Graduate Attributes (*Learning Outcomes* expected from all graduate engineers)

On completion of an accredited program of study typified by four years or more of post-secondary education, a student should be able to:

i. Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the conceptualization of engineering models.

ii. Identify, formulate, research literature and solve **complex engineering problems** reaching substantiated conclusions using first principles of mathematics and engineering sciences.

iii. Design solutions for **complex engineering problems** and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

iv. Conduct investigations of **complex engineering problems** including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions

v. Create, select and apply appropriate techniques, resources, and modern engineering tools, including prediction and modeling, to **complex engineering activities**, with an understanding of the limitations

vi. 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.

vii. Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.

viii. Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering practice.

ix. Understand and commit to professional ethics and responsibilities and norms of engineering practice.

x. Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development.

xi. Demonstrate a knowledge and understanding of management and business practices, such as risk and change management, and understand their limitations.

xii. Recognize the need for, and have the ability to engage in independent and life-long learning.

Definitions of Complex Engineering Problems

Engineering problems which cannot be resolved without in-depth engineering knowledge and having some or all of the following characteristics:

- Involve wide-ranging or conflicting technical, engineering and other issues
- Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models
- Requires in-depth knowledge that allows a fundamentals-based first principles analytical approach
- Involve infrequently encountered issues
- Are outside problems encompassed by standards and codes of practice for professional engineering
- Involve diverse groups of stakeholders with widely varying needs
- Have significant consequences in a range of contexts
- Are high level problems possibly including many component parts or sub-problems

Definitions of Complex Engineering Activities

Complex Engineering Activities means activities or projects that have some or all of the following characteristics:

- Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials, information and technologies)
- Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues,
- Involve creative use of knowledge of engineering principles in novel ways

- Have significant consequences in a range of contexts
- Can extend beyond previous experiences by applying principles-based approaches

3. Responsibilities of the Reviewer

***Section Summary**: In this section we take up the 11 issues on which the reviewers have been asked to comment. The first two issues are not easy to comment on with any great objectivity. Some examples of reasonably well stated Mission, Vision and the corresponding PEOs have been shown to illustrate the point. The third issue also is a little tricky to comment on. The most important issue of Instructional objectives has been discussed with specific examples.*

1. **To comment if the mission and the vision of the institute have been stated appropriately**
2. **To verify if the PEO is consistent with the stated mission and vision of the institute.**

***Comments:** Many variations are possible. Here are some examples. They are all reasonably appropriately stated and the PEOs seem sufficiently consistent.*

❖ **Course Name: Automata Theory and Formal Language**

Stated Institute's Mission

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Providing academic freedom to each faculty to carve out a niche in the global arena of academic fraternity and to strive to enhance our brand image.
- Fostering product oriented research for establishing a self-sustaining and wealth creating center to serve the societal needs

Institute's Vision

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society.

Program Objectives of Computer Science Department

a. Progress in their professional careers with leadership roles in activities such as research, experimental studies and industrial projects.
b. Pursue further studies and embrace lifelong learning in areas relevant to Computer Science & Engineering.

c. Be capable of working effectively and cooperatively in a dynamic, globalized professional environment;
d. Become good citizens who live with demonstrated ethical, professional standards and having enthusiasm for contributing to the profession and professional growth.

❖ Course Name: Digital Control

Institute's Mission

• **Motto of IIT Bombay**: ”Gnayanam Paramam Dhyeyam” (Knowledge is the Supreme Goal).
• **Vision**: To be the fountainhead of new ideas and of innovators in technology and science.
• **Mission**: To create an ambience in which new ideas, research and scholarship flourish and from which leaders and innovators of tomorrow emerge.
• **Strategy**: IIT Bombay’s Mission and Strategy document addresses ”Innovations in Education” as one of its key issues initiatives.
<u>Innovations in education</u>
We will strengthen and enhance our educational activities to enable increased cross-disciplinary learning, greater flexibility in programmes and increasing use of web-based learning.
– Encourage open-ended problem-solving and independent study
– Encourage cross-disciplinary courses at senior levels
– Increase the flexibility of progammes and decrease the number of courses required
– Provide for more categories of students including students living off-campus and part-time students
– Evolve a policy for web-based education as a supplement to classroom education

Corresponding PEO not stated

❖ Principles of Industrial Engineering

Institute's Mission
“To create an environment that shall foster the growth of intellectually capable, innovative and entrepreneurial professionals, who shall contribute to the growth of Science and Technology in partnership with industry and develop and harness it for the welfare of the nation and mankind”.

Institute's Vision
“To be the fountainhead of new ideas and innovations in science and technology and continue to be a source of pride for all Indians”.

Program Objectives
The Department of Mechanical and Industrial Engineering has been offering dynamic educational programs since 1946 with a mission to provide quality engineering education

and contribute new knowledge through research in Mechanical and Industrial engineering and allied disciplines. The educational objectives of the department are to ensure that the students: **1**. graduate with robust problem-solving skills; **2.** acquire skills to clearly communicate technical concepts; **3**. acquire ability to readily work with other disciplines; **4.** fulfill professional and ethical responsibilities in the practice of mechanical or production and industrial engineering, including social, environmental and economical considerations; **5.** engage in life-long learning activities; **6.** understand the impact on the economic, engineering, environmental, and social issues from an engineering context in a global scenario; **7.** develop a professional career in the existing market that meets personal goals, objectives and desires.

A very well written PEO, well matched with the mission and the vision statements excepting that there is no attempt on the part of the department to produce "*entrepreneurial professionals*" as stated in the mission statement. However, had it been a part of the PEO, then a suitable course would have to be part of the compulsory course work.

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3. **To verify if the compulsory courses selected are consistent with the stated PEO**

   Comments: If a PEO specifically emphasizes a particular sub area of a discipline or a special set of skills as the strength of the degree programme, then more often than not, some directly related courses have to be taken by all students. Additionally the course objectives must also reflect how these claims are proposed to be met.

4. **To verify if the course objectives and the course overview are consistent with the PEO**

   Comments: Here are some examples of course objectives with comments and suggestions.

Course: Introduction to Algorithm Design

Course Objectives

Students pursuing this course should be able to

1. Given an English language problem description, define the problem precisely with input/output requirements, examine its inherent complexity and develop a generic or set of initial solutions (which can be explored for various design options) and justify their correctness.
2. Given an algorithm description, analyze the time and space complexity of the algorithm in the worst case, average case and amortized scenario as needed in terms of asymptotic orders of complexity.
3. Given a problem definition, explore different alternative algorithmic solutions, compare them with respect to time and space complexity and choose the design schemes and/or design parameters and data structures appropriately to obtain the best possible choice(s) that can be converted to an executable program.

4. Design and analyze algorithms using the methods studied to solve problems in important applications including those related to sorting, searching, strings, graphs, matrices, data structuring and combinatorial optimization.
5. Examine and prove whether a problem is of polynomial complexity, hard (NP-Complete) or otherwise and develop optimal and approximation algorithms for them as applicable.

Comments and suggestions:

a) **This is an excellent example of Course Level Objectives. All objectives require high level cognitive skills (application, analysis, synthesis/design, evaluation etc). They are demanding and have the potential to bring out the best in students.**

b) **The objectives selected, not only fulfill the demands of the specific course (domain knowledge), but also fulfill the first 5 Learning Outcomes mentioned under section 2.2.3 Outcome-based Learning (generic skills).**

c) **All objectives have been written using appropriate action verbs which leave very little room for different interpretation by different people. The objectives specify what the students are able to do at the end of a course, rather than what the course is all about. Proof of their ability to perform these actions through appropriate tests may be taken as the evidence that they have achieved the objectives.**

d) **The first 3 Instructional Objectives also include the *Condition Components* such as**
given an English language problem description; given an algorithm description; given a problem definition, using the methods studied **Ideally all well written Instructional objectives should include condition components to specify under what condition the learner should be able to do what is expected of them, but many instructors miss this clause.**

e) **The third important component of a well written instructional objective is the criteria of acceptable performance describing how well the learner must perform to be considered acceptable.**

f) **These instructional objectives**
   - **are set at levels which are very appropriate for engineering degree programme in CSE in a tier 1 institution**
   - **fulfill many learning outcomes**
   - **are expressed using correct action verbs, including condition components and defining purpose (**which can be explored for various design options; as needed in terms of asymptotic orders of complexity; that can be converted to an executable program) **for additional clarity.**
   - **are sufficiently comprehensive to serve as Course Objectives.**

Course: Principles of Industrial Engineering

Course Objectives

On completion of this course, the ~~reader~~ (learner) will be able to:

- ~~understand~~ the meaning of the terms industry, organization, and factory;
- compare different organizational structures and their suitability;
- explain the significance of industrial engineering functions in a factory system;
- identify factors that influence factory location;
- analyze different types of factory layout;
- design layout for specific factory;
- select suitable material handling device(s) according to the requirements;
- identify the need for different production operations systems;
- use different qualitative and quantitative forecasting techniques;
- compute demand forecasting for product/service using different techniques;
- ~~understand~~ different techniques of scheduling;
- develop job sequence for given shop floor data;
- apply different project management techniques for evaluation of work schedules;
- ~~appreciate~~ and explain the need and scope of inventory management;
- classify and analyze inventories in an organization using different methods of inventory analysis;
- ~~understand~~ the concepts of quality, statistical quality control (SQC), total quality management (TQM) and quality function deployment (QFD);
- ~~appreciate~~ the needs for quality and quality inspection;
- construct control chart for variables and control chart for attributes;
- ~~understand~~ and analyze the importance and scope of work study in improving productivity of an organization;
- ~~understand~~ the significance of ergonomic design in improving efficiency/performance;
- create graphical representations like operation process chart, flow diagram and activity charts;
- compare, examine and analyze the graphical tools and develop the ‘best’ method of doing the work

[Edited by the author of this document to draw attention to the problems]

Comments and suggestions:

a) **Fairly comprehensive. At course level, many similar objectives are usually combined so that typically a course has no more than 5-8 groups of objectives.**
b) **One or two verbs (understand, appreciate) are not action verbs. “Understand” may be replaced by one of the suitable action verbs specified for the “comprehension” level of learning in the cognitive domain (annexure 1).**

Course: ABCDEF……

Course Objectives

1. The course will provide a technical orientation to xxxxxxxxxxxxxx
2. The course will develop an awareness regarding yyyyyyyyyyyy

3. The course will provide an overview on various zzzzzzzzzzzzzzzzz.
4. The course will reveal different technologies to design aaaaaaaaaaaaaaa
5. Will generate interest for doing higher studies/research in this field.
6. To promote efficient use of acfsvdbfhgy related to nhgbvfdcaser
7. How to aaaaaaaaaaa and to improve abcdabcdabcd.

Comments and suggestions:

a) **None of the above specifies what the learner will be able to DO (performance component) under what given situation (condition component) or what the criteria for acceptance are?**
b) **None of the above remotely resembles Instructional Objectives and hence will render the rest of the work invalid. Without a clearly defined set of instructional objectives, it is impossible to write problems, assignments which test the achievement of those objectives.**
c) **Very major rework is called for.**

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5. **To verify if the modules are logical and if the module objectives and module overviews are consistent with the course objectives and course overview**
6. **To verify if the unit objectives are consistent with the module objectives and module overview**
7. **To verify if the course/module/unit objectives are in alignment with the specified learning outcomes.**
8. **To verify if the problems / assignments etc**
   i. **are original in nature and test the achievement of unit / module / course level learning objectives**
   ii. **are adequate in number [for details please see sub sections (6) and (7) and (8) of section 1.4]**
   iii. **are non-trivial, clearly formulated, easily comprehensible**
   iv. **covers all the objectives adequately**
   v. **have necessary information to solve the problems, assignments**
9. **To verify if the suggested learning strategies are likely to achieve the stated learning objectives and the learning outcomes (please see annexure 3 for additional information)**
10. **To comment on the overall quality of the work (on a scale of 7… 1: very poor ; 7: exceptional)**
11. **Any other comment thought fit by the reviewer**

The last seven issues (5-11) are self explanatory and need no guidance.

Annexure 1

Action verbs for stating Behavioral Objectives in the Cognitive Domain

Knowledge: Remembering previously learnt material

Cite, label, name, reproduce, define, list, quote, pronounce, identify, match, recite, state

Comprehension: ability to grasp the meaning

Alter, discover, explain, rephrase, substitute, convert, give examples, summarize, give idea, restate translate, describe, illustrate, reword , interpret, paraphrase

Application: ability to use learned material in new and concrete situations

Apply, relate, classify, employ, predict, show, compute, prepare, solve and demonstrate

Analysis: ability to break down material into its component parts so that its organizational structure may be understood.

Ascertain, diagnose, distinguish, outline, analyze, divide, point out, associate, differentiate, examine, reduce, conclude, discriminate, find, separate, designate, dissect, infer, determine

Synthesis: ability to put parts together to form a new whole

Combine, devise, originate, compile, expand, plan, compose, extend, synthesize, conceive, generalize, revise, create, integrate, project, design, invent, rearrange, develop, modify

Evaluation: ability to judge the value of material for a given purpose

Appraise, conclude, critique, judge, assess, contrast, deduce, weigh, compare, criticize, evaluate.

Contd.

Annexure 2

Psychomotor Domain includes physical movement, coordination, and use of the motor-skill areas. Requires practice, measured in terms of - speed, precision, distance, procedures, or techniques in execution

Imitation **Manipulation** **Precision** **Articulation** **Naturalization**

Imitation:

Observing and patterning behavior after someone else. Performance may be of low quality. May repeat an act that has been demonstrated or being able to perform certain actions by following instructions and practicing - until it becomes habitual. Learner still isn't "sure of him /herself**.**

Example: Creating work of art on one's own, after taking lessons, or reading about it.

Precision:

Refining, becoming more exact skill has been attained. Proficiency is indicated by a quick, smooth, accurate performance, requiring a minimum of energy. The overt response is complex and performed without hesitation. Few errors are apparent.

Example: Working and reworking something, so it will be "just right“.

Articulation:

Coordinating a series of actions, achieving harmony and internal consistency, involving an even higher level of precision. The skills are so well developed that the individual can modify movement patterns to fit special requirements or to meet a problem situation.

Example: Producing a video that involves music, drama, color, sound,

Naturalization:

Having high level performance- becomes natural, without needing to think much about it - response is automatic. The individual begins to experiment, creating new motor acts or ways of manipulating materials out of understandings, abilities, and skills developed.

Example: Michael Jordan playing basketball

Affective Domain:

Receiving **Responding** **Valuing** **Organizing** **Characterizing**

Receiving - is being aware of or sensitive to the existence of certain ideas, material, or phenomena and being willing to tolerate them

Responding - is committed in some small measure to the ideas, materials, or phenomena involved by actively responding to them.

Valuing - is willing to be perceived by others as valuing certain ideas, materials, or phenomenon

Organization - is to relate the value to those already held and bring it into a harmonious and internally consistent philosophy**.**

Characterization- by value or value set **-** is to act consistently in accordance with the values he or she has internalized.

Annexure 3

This is an example, randomly selected from the list of courses under development to explain the importance of setting appropriate objectives and adopt appropriate teaching learning strategies.

COURSE OBJECTIVES	LEARNING OUTCOMES*											
	1	2	3	4	5	6	7	8	9	10	11	12
• Given an English language problem description, define the problem precisely with input/output requirements, examine its inherent complexity and develop a generic or set of initial solutions (which can be explored for various design options) and justify their correctness.	3	3	3	3	3	2	?	-	-	-	-	?
• Given an algorithm description, analyze the time and space complexity of the algorithm in the worst case, average case and amortized scenario as needed in terms of asymptotic orders of complexity.	2	3	3	3	3	2	?	-	-	-	-	?
• Given a problem definition, explore different alternative algorithmic solutions, compare them with respect to time and space complexity and choose the design schemes and/or design parameters and data structures appropriately to obtain the best possible choice(s) that can be converted to an executable program.	2	2	3	3	3	2	?	-	-	-	-	?
• Design and analyze algorithms using the methods studied to solve problems in important applications including those related to sorting, searching, strings, graphs, matrices, data structuring and combinatorial optimization.	3	3	3	3	3	2	?	-	-	-	-	?
• Examine and prove whether a problem is of polynomial complexity, hard (NP-Complete) or otherwise and develop optimal and approximation algorithms for them as applicable.	2	2	2	3	3	2	?	-	-	-	-	?

*** The description of learning outcomes no 1 -12 are given below.**

The numbers 1, 2 or 3 entered for a particular objective (rows) and a particular Outcome (columns), indicate how well that objective will address the corresponding outcome. A ? mark denotes that the grade (1/2/3) will depend on the teaching/ learning strategy followed by the instructor / learners. For example, if the strategy of collaborative group learning, self learning is as a common practice then the grades would be high for those learning outcomes.

1= Objective addresses corresponding Learning Outcome marginally

2= Objective addresses corresponding Learning Outcome somewhat satisfactorily

3= Objective addresses corresponding Learning Outcome very satisfactorily

OUTCOME NO	DESCRIPTION OF LEARNINING OUTCOMES
1.	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the conceptualization of engineering models.
2.	Identify, formulate, research literature and solve complex engineering problems reaching substantiated conclusions using first principles of mathematics and engineering sciences.
3.	Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
4.	Conduct investigations of complex engineering problems including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions
5.	Create, select and apply appropriate techniques, resources, and modern engineering tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations
6.	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.
7.	Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
8.	Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering practice.
9.	Understand and commit to professional ethics and responsibilities and norms of engineering practice.
10.	Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development.
11.	Demonstrate a knowledge and understanding of management and business practices, such as risk and change management, and understand their limitations.
12.	Recognize the need for, and have the ability to engage in independent and life-long learning