REVISED EDITION

HANDBOOK

OUTCOME BASED EDUCATION

ENGINEERING

Prof. N.J. Rao

KERALA STATE HIGHER EDUCATION COUNCIL

2023

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Handbook -Outcome Based Education

(Engineering)

Revised Edition

(Material presented here was liberally borrowed from the references given)

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Preface

Higher Education in India is undergoing major changes since 2015. One important change is shifting the focus from what is taught to what is learned. This is formally known as Outcome Based Education (OBE). OBE is an approach to education in which decisions about the curriculum and instruction are driven by the exit learning outcomes that the students should display at the end of a program or a course. A system based on outcomes gives priority to ends, purposes, learning, accomplishments, and results. While this shift to student centricity appears to be the right way, it calls for important changes to the existing beliefs and practices of teaching and learning. These include how the syllabus of course is communicated to the learners, the way instruction needs to be done, how the assessment of learning is done, and how the attainment of educational goals (learning outcomes) is determined.

All institutions offering higher education programs in India need to be accredited by the National Assessment and Accreditation Council (NAAC). OBE and some criteria of the NAAC can serve as excellent framework for design and conduct of courses in general higher education programs without curtailing the academic freedom of the teachers in any way. This booklet presents why and what of OBE, features of Revised Bloom's taxonomy of learning, teaching, and assessment, and how to write Outcomes of a Course in higher education programs as per the criteria of the NAAC. This document evolved through many Faculty Development Programs (FDPs) conducted across the country over the last seven years, and inputs from the participating faculty. I am particularly thankful to the FLAIR programs and the FDPs organized by the Kerala State Higher Education Council. I hope this and other companion booklets become pedagogical associates to the practicing and aspiring faculty of higher education institutions.

N. J. Rao

November 2022

Towards Outcome-Based Education[1]

Science and technology have caused the appearance of a variety of pedagogic strategies that have acquired presence in almost all educational systems. Although this has opened enormous possibilities for students and teachers to make use of, some important questions continue to haunt educational systems everywhere. Hardly any breakthrough has been achieved regarding teaching or how to learn. Slightly altered versions of earlier rote-learning, which compel students to reproduce whatever is conveyed to them by their teachers, remain still valid. Students must learn what the system or teachers as representatives of the system, chooses to teach them and at the end of such educational transactions they must face a test set by the very same system.

There is no scope for students to frame their questions or exercise freedom to ask questions in their own way. Portions of the syllabus for any academic programme require rethinking against the background of changes occurring in society as well as at the level of knowledge attained in the domain concerned. Often many things already learnt recur at higher stages not only adding to the tedium of familiarity but also rendering the obsolete plausible again, rather than letting students unlearn them. Same lessons indiscriminately passed on to higher levels impede the process of learning by turning it into mere memorizing.

Understanding ceases with the precedence of remembrance over it. Such aberrations should never happen in a very serious and sensitive area of human endeavour like education. That such a situation prevails, despite technological advances providing for effective ways of teaching how to learn systematically by unlearning, is an issue quite frustrating. This is one of the most important problems that the world higher education encounters in the wake of the techno-economic globalization that shakes the core of the production of knowledge. It is a fact that the exponential rate of the so-called knowledge production has shot up amazingly high, but a majorKerala State Higher Education Council (2022) Outcomes are presented as items which should inevitably be attained by every student at the end of his or her educational experiencepart of such knowledge is mere information. As a result, transmission of knowledge has become even more mechanical and alienating. Naturally, the quality of teaching and learning has become abysmally poor. Naming this kind of inappropriate production and transaction of knowledge as education is being questioned very seriously. Teaching how to learn and deepening learning through systematic unlearning must be resuscitated as inevitable constituents of quality assurance. In the context, Outcome-based Education (OBE) has been gaining obsessive emphasis to achieve quality. OBE is based upon an educational theory which integrates every aspect of educational system with a set of avowed outcomes.

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Outcomes are presented as items which should inevitably be attained by every student at the end of his or her educational experience. OBE insists upon determination of learning outcomes as the first step in course designing. Outcomes which are decided upon should evolve out of the contents, instructional strategies, learning experiences, methods of evaluation and the assessment. At different levels of higher education, each course should have its own expected outcomes, explained logically through a linked process which can be defended as to its ability to produce graduates with predetermined outcomes. The worthiness or desirability of the whole course can be prejudged before its implementation, by the defensibility of its objectives, namely the outcomes, and how they can be achieved through the several steps contained in the process.

Outcomes are presented as items which should inevitably be attained by every student at the end of his or her educational experience

Precisely drawn specific outcomes provide clarity of purpose in teaching/learning. They act as a running thread of quality control across the planning of curriculum, selection of instructional strategies, choice of learning experience and preparation of tests. Informing learners about the outcome well in advance, OBE enables ongoing concurrent self-assessment of learners for making sure of their progress towards attaining the outcome. It provides them with chances to demand new learning experiences that ensure outcome. Since the outcomes are stated, the teachers alsoget to know the progress, and they enjoy the legitimate right to test whether the learners have attained the goal. In such a system, teachers become lucid about teaching how to learn and students, clear about learning how to create. If in the earlier system, teaching was defined as a task to be carried out within the syllabus–curriculum set framework; under OBE, it becomes a definite responsibility to be carried out in such a way as to meet the objectives or outcomes. Similarly, students under the new system get opportunity as well as reasons to chart out their own innovative ways of learning. Transcending the stereotypical, OBE provides opportunities to learn differently, naturally, and creatively. It is mastery learning but with criticality and creativity. Once OBE is accepted, the differences between types of institutions do not matter so much, as between distance learning or campus-based learning. What matters is whether the graduate has attained the objectives set for the course. It is true that within the prevalent pedagogic or andragogic process, there are several gaps, both in terms of curriculum objectives and in terms of syllabus-based transaction, which make the final test itself superfluous. On the contrary, OBE provides a tightly spelt-out process, the internal parts of which are logically linked to one another. Obviously, OBE is a very transparent system right from curriculum planning to the declaration of the assessment result. However, we cannot uncritically accept OBE and hail it as a panacea. There are several factors that hold us sceptical about it. For instance, who or what combination of forces will be instrumental in setting the objectives or outcomes is a crucial question. In a techno-economically globalized world the general objectives may be set globally based on the requirements of reproducing such a universal system.

OBE may also be biased in producing and reproducing the techno-economic system that is already predominant. Insistence upon determining the outcomes beforehand is logically the same that we see in any of the projects in the economy, which rigorously spell out their deliverables in advance. Just as the earlier system/systems demanded uncritically recreating the main features that were already predominant, OBE may also in a more efficient manner be doing the same. Therefore, it is extremely important to be cautious about such lurking dangers of the system and evolve strategies to counter them.

OBE may also be biased in producing and reproducing the techno-economic system that is already predominant. It is extremely important to be cautious about such lurking dangers of the system and evolve strategies to counter them.

A crucial step is to ensure that specific internal features of OBE are set forth as fool proof. The internal logic which leads the system towards outcomes and the way in which creative and innovative methods are encouraged to be adopted, will reduce the possibilities of deadpan repetition as could be doubted. Nevertheless, a reason for favouring OBE is that hardly can we escape the global strategies of standardization, classification, and ranking. Whether we wish it or not, international accreditation agreement for professional courses is mandatory. Powerful motives of economies of scale and advantages for use for further processing are behind it. In such a situation, professional courses will be expected to be part of a standardized world-wide system.

Courses and Credits in the General Stream too must be precisely defined in alignment with international standards. Strengthening teaching/learning system in higher education institutions today means a package of curriculum design, course design, instruction design, and test design following global standards. Re-articulation of higher education in tune with OBE is no more a matter of choice today. Such discussions are to be encouraged in educational planning.

Prof. (Dr) Rajan Gurukkal is Chief Editor of Higher Education for the Future and Vice Chairman of Kerala State Higher Education Council

Foreword

The Higher Education Institutions (HEIs) in the State are in the threshold of a major transformation especially in the realm of curricular reforms. This is in line with the global and national development in the structure and content of higher education. Major changes are being implemented in teaching -learning at the undergraduate level involving a thorough transformation in the teaching -learning process. Outcome Based Education (OBE) forms an integral part of the curricular reforms. The emergence of new areas of knowledge and technological changes are to be integrated in to the whole system of higher education. There are several liberal arts, humanities and social sciences of great relevance not appropriately promoted in the Higher Education Institutions of Kerala. The technological adoption must be sophisticated enough to be in perfect alignment with Outcome Based Education (OBE).

Assessment methods have to be based on Blooms action verbs or stem words for ascertaining the knowledge categories and cognitive levels. Institutions especially universities and colleges have to bring about necessary changes in the organizational structure for facilitating the OBE based evaluation as new normal in higher education institutions. In this context, Faculty Development Centre (FDC) of the Kerala State Higher Education Council has been organizing

several training programmes on OBE for the benefit of teachers in government/ aided/ self-financing colleges. The universities in the state are taking all out efforts to define the Graduate Attributes of programmes and curriculum /syllabi are being restructured to integrate OBE at all levels of teaching and evaluation.

I congratulate Dr. Manulal P. Ram, Research Officer and the academic staff of the Faculty Development Centre for their excellent work and pain staking efforts under the leadership of Prof Rajan Gurukkal, Vice Chairman, KSHEC in bringing out this Handbook on Outcome Based Education for both general and engineering streams. I also appreciate the wholehearted efforts of Prof N. J. Rao, (IISc, Bangalore) and his team in this important endeavour. I also thank the faculty of various universities/ colleges for their enthusiastic participation and suggestions in the Faculty Development Programmes which really improved the content of this book.

28.02.2023
Thiruvananthapuram

Dr. Rajan Varughese
Member Secretary

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CHAPTER 1

Introduction

1. What is Outcome Based Education?

Learning is supposed to have occurred when we can do something that we could not do earlier. Learning leads to acquiring new knowledge, behaviors, skills, values, preferences, or understanding and sometimes involves synthesizing different information types. According to Kolb, learning is the process whereby knowledge is created (knowledge production) through the transformation of experience. Outcomes of Learning or 'learning outcomes' are what the student should do at the end of a learning experience. Learning experiences in formal higher education programs can be identified as learning units. A unit of learning maybe a few hours of self/classroom learning activity, a one-semester course, or a formal program of two to four years.

The outcomes of learning are also referred to as Outcomes, Learning Outcomes, Intended Learning Outcomes, Instructional Objectives, Educational Objectives, Behavioural Objectives, Performance Objectives, Terminal Objectives, Subordinate Skills, Subordinate Objectives, General Instructional Objectives, Specific Learning Outcomes, and Competencies.

An outcome of education is what the student should do at the end of a program/course/ instructional unit. An outcome is a functional ability, including attributes, skills, and knowledge.

William Spady introduced Outcome Based Education (OBE) in the early 90s for the American School system. Higher education systems adopted OBE eventually by shifting the focus from what is taught to what is learned. OBE is an approach to education in which decisions about the curriculum and instruction are driven by the exit learning outcomes that the students should display at the end of a program or a course. It facilitates establishing the conditions and opportunities within the system that enable all students to achieve those essential outcomes. A system based on outcomes gives priority to ends, purposes, learning, accomplishments, and results.

There are several advantages to working with Outcome-Based Education.

- **Clarity**: An explicit statement of what the educational process aims to achieve clarifies the curriculum to both students and teachers and focuses on teaching and learning.
- **Provision of a Framework**: Outcome-based education provides a robust framework for integration of the curriculum.
- **Guide for Assessment**: The outcomes provide the framework for student examinations.

- **Facilitates Curriculum Evaluation**: The outcomes provide benchmarks against which the curriculum can be judged.

Conducting teaching-learning processes in any framework is not acceptable to some teachers and is taken against the spirit of education. Any framework presented is immediately branded as a straitjacket. If the teacher is a 'subject expert sage' and the students are highly cognitively competent, there is no need for any framework. Such a combination of sages and students is scarce in higher education institutions of India. Even the top-ranked institutions must follow the procedures related to positive discrimination and be concerned with equity and access issues. OBE merely asks the teacher to communicate at the beginning of the semester what students are expected to do at the end of a semester (course outcomes) rather than the mere list of topics. It has been established through systematic research and field studies. Communicating the course outcomes to students at the beginning of the semester makes a significant difference to students' performance. Outcome-based education does not interfere with the academic freedom of the teacher. It merely asks the teacher to follow a process in offering a course. The process consists of writing course outcomes (what the students should be able to do), designing assessment (how to measure the ability of students to do what they are expected to do), and instruction (how the teacher proposes to facilitate the students to acquire the ability to do what they are supposed to do). The teacher makes all the decisions in all three steps of the process. That is certainly not a definition of a straitjacket. The accreditation agencies require that all institutions write the outcomes, communicate them to stakeholders, particularly to students, and determine the attainment of these outcomes.

Outcome based education does not interfere with the academic freedom of the teacher. It merely asks the teacher to follow a process in offering a course

This note presents a method of writing outcomes for Engineering undergraduate degree programs. The proposed method is in the framework of current pedagogical theories and was heavily field tested through faculty development workshops. Material from the indicated references was used liberally in preparing this document.

The accreditation agencies require that all institutions write the outcomes,communicate them to stakeholders, particularly to students, and determine the attainment levels of these outcomes.

CHAPTER 2

Outcomes

Outcomes are the abilities the students acquire and demonstrate at the end of a learning experience. The learning experience can be an instructional unit that involves a small number of hours of instructional activity, a course of one-semester duration, or a two to four-year formal undergraduate program. Outcomes serve as the basis for productive interaction among concerned stakeholders. The outcome can also be called a 'learning product' since the outcome is the product of learning. Therefore, the "product defines the process" in OBE. It is results-oriented thinking and is the opposite of input-based education, where the emphasis is on the educational process and where we are happy to accept whatever is the result. Outcome-based education is not merely producing outcomes for an existing curriculum**.**

Outcomes/Objectives can be defined at three levels in the case of undergraduate programs in engineering.

Program Educational Objectives: PEOs (Program Educational Objectives)are broad statements that describe the career and professional accomplishments in four to five years after graduation that the program is preparing graduates to achieve.

Program Outcomes and Program Specific Outcomes: Program Outcomes (POs) are statements that describe what the students graduating from undergraduate engineering programs should be able to do. Program Specific Outcomes (PSOs) are statements that describe what the graduates of a specific program should be able to do.

Course Outcomes: COs (Course Outcomes) are statements that describe what students should be able to do at the end of a course.

Program Educational Objectives: An engineering program is designed to prepare students to perform wealth-generating and socially relevant activities in their training and related areas. A program expresses its intent through its PEOs. They can be three to five in number.

Sample PEOs: Graduates of the BE program of **Mechanical Engineering** after four to five years after graduation will

PEO1. Design and evaluate mechanical components and systems using state-of-the-art IT tools.

PEO2. Plan manufacturing of given mechanical components and systems and design quality assurance systems.

PEO3. Practice modern management to manufacturing of components and systems.

PEO4. Work in a team using standard tools and environments to achieve project objectives.

Most of the graduates in Mechanical Engineering should be performing a subset of these activities during the four to five years after graduation.

Program Outcomes: Engineering undergraduate degree is the terminal degree for most engineering graduates (>80%). They get into employment not necessarily related directly to the discipline of their program. Whatever the profession the graduates get into, they need to have some abilities and attitudes that make them good employees and contribute to the organization's wealth generation and service activities. In any organization, the employees must work as teams arranged in some hierarchy, communicate well in verbal and written form with peers and customers, and understand their impact on society. Program Outcomes (POs) students are what all students are required to attain when graduating from an engineering program. A national agency usually identifies the POs of professional programs. In the case of Engineering programs, the National Board for Accreditation (NBA) determines the POs. POs are non-specific to the discipline of the program. Sometimes these are referred to as liberal education and common core competencies. Some sample POs from the 12 POs identified by the NBA are:

> *Program Outcomes (POs) students are what all students are required to attain when graduating from an engineering program*

PO1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling to complex engineering activities with an understanding of the limitations.

Program Specific Outcomes: PSOs are outcomes that are specific to a program. They characterize the specificity of the core (core courses) of a program. PSOs of any engineering undergraduate program can only be two to four in number.

Sample PSO of a **Computer Science and Engineering** program

> Specify, design, develop, test, and maintain usable software systems that behave reliably and efficiently and satisfy all the requirements that customers have defined for them.

Sample PSO of an **Electronics and Communication Engineering** program

> Specify, design, prototype, and test modern electronic systems that perform analog and digital processing functions.

Sample PSO of a **Civil Engineering** program is

Specify, design, supervise, test, and evaluate foundations and superstructures for residences, public buildings, industries, irrigation structures, powerhouses, highways, railways, airways, docks, and harbours.

Sample PSOs of a **Mechanical Engineering** program is

PSO1. Design mechanical components and systems as per given specifications using EDA tools.

PSO2. Specify and design thermal systems, including heat exchangers, condensers, evaporators, air-conditioners, refrigeration systems as per given specifications.

PSO3. Specify and design turbomachines, including air compressors, hydraulic turbines, and pumps, as per the given specifications.

PSO4. Plan manufacturing (methods design, process plan, quality assurance systems, and process automation) of given mechanical components and systems.

The PSOs need to be written by the concerned Boards of Studies.

COs: Course Outcomes (COs) represent what the students should be able to at the end of a course. They will be discipline and subject specific. Some sample COs from various courses

- Determine Power System parameters under unbalanced conditions using Symmetrical Components.
- Determine the time and space complexity of iterative and recursive algorithms.
- Write programs for one-dimensional and two-dimensional array manipulation and string handling functions.
- Understand the behavior of single effect and multiple effect evaporators.

The teacher(s) offering the course, or the Board of Studies of the concerned program write the Course Outcomes.

The relationships among the three Outcomes/Objectives as per the NBA are shown in figure 1. It should be noted that well-defined processes need to be defined and followed for writing and modifying the outcomes/objectives.

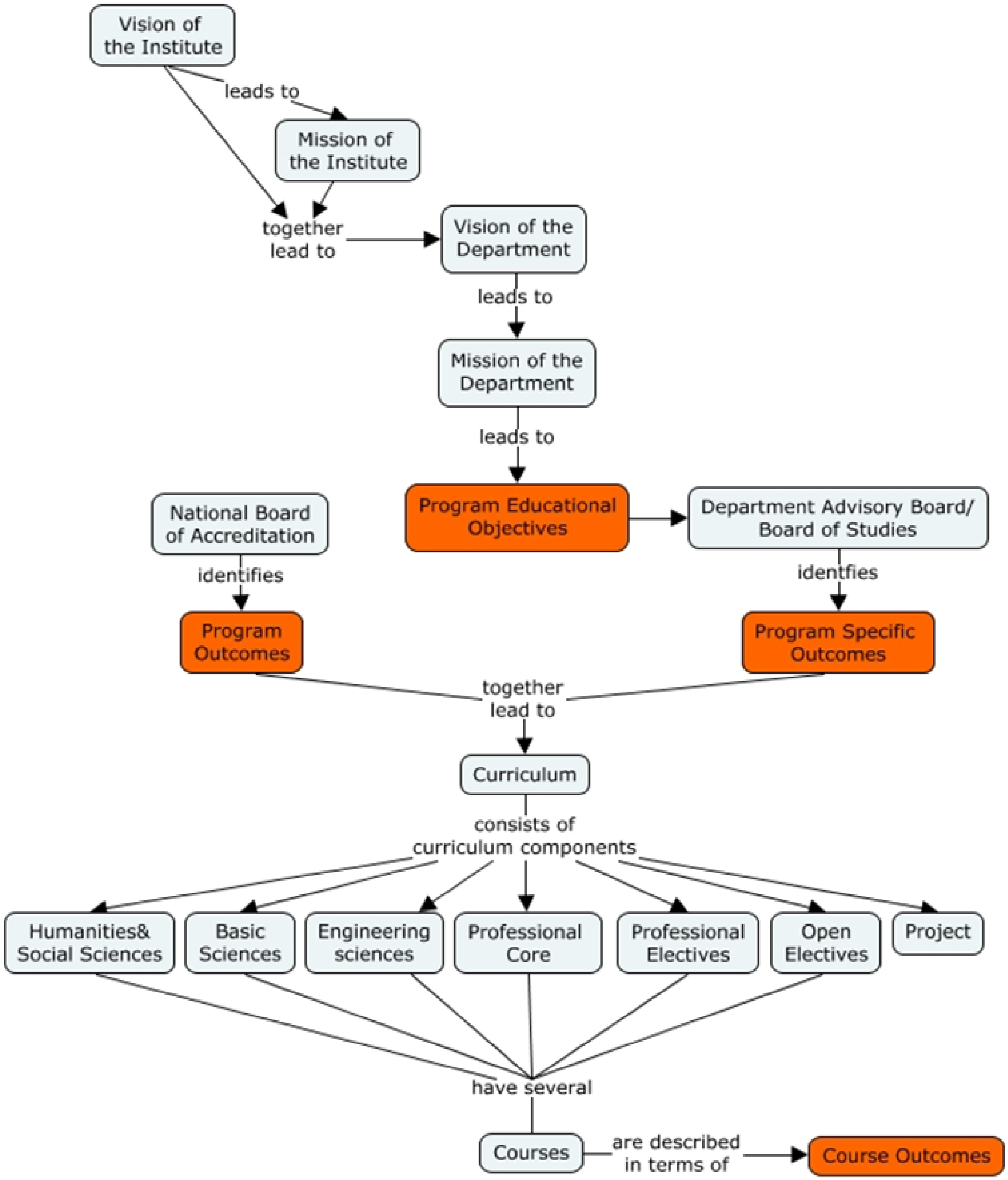

Fig. 1: Outcomes and Objectives in NBA framework

CHAPTER 3

Taxonomy of Learning

3.1 What is Taxonomy of Learning

In 1956, Benjamin Bloom headed a group of educational psychologists who developed a classification of intellectual behavior levels important in learning. This classification became a taxonomy with three overlapping domains: cognitive, psychomotor, and affective. Cognitive learning is demonstrated by recalling knowledge and intellectual skills: comprehending information, organizing ideas, analyzing, and synthesizing data, applying knowledge, choosing among alternatives in problem-solving, and evaluating ideas or actions. This domain on the acquisition and use of knowledge is predominant in most courses. Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts as the lowest level, through increasingly complex and abstract mental levels, to the highest order, evaluation. The six progressive stages of cognitive thinking are identified as knowledge (recall), comprehension, application, analysis, synthesis, and evaluation. Bloom's initial work was followed up with research that resulted in a list of Action Verbs representing intellectual activity on each cognitive domain's respective level.

Krathwohl (1964) took the lead to produce a parallel taxonomy explaining the development of attitudes, principles, codes, and human values. Affective learning is demonstrated by behaviors indicating attitudes of awareness, interest, attention, concern, responsibility, ability to listen and respond in interactions with others, and the ability to demonstrate those attitudinal characteristics or values appropriate to the test situation and the field of study. This domain relates to emotions, attitudes, appreciations, and values, such as enjoying, conserving, respecting, and supporting. Six progressive stages constitute personal growth in the affective domain: affective perceiving, reacting, conforming, validating, affective judging, and affective creating. Verbs applicable to the affective domain include accept, attempt, defend, dispute, join, judge, praise, question, share, support, and volunteer.

Kibler et al. (1970) completed the trilogy of taxonomies with the physical dimensions of behavior as it develops from gross to fine movements and nonverbal to verbal activities. Psychomotor learning is demonstrated by physical skills; coordination, dexterity, manipulation, grace, strength, speed; actions that demonstrate the fine motor skills such as the use of precision instruments or tools, or actions that evidence gross motor skills such as the use of the body in dance or athletic performance. The categories include psychomotor perceiving, activating, executing, maneuvering, psychomotor judging, and psychomotor creating. Verbs applicable to the psychomotor domain include bend, grasp, handle, operate, reach, relax, shorten, stretch, write, differentiate (by touch), express (facially), perform (skilfully).

Together, these taxonomies for cognitive learning, social interaction, and physical development are the recognized building blocks for creating measurable learning outcomes, planning instruction, and measuring the attainment of outcomes.

Bloom's taxonomy has been revisited several times by educational psychologists, and several variants of the original taxonomy were proposed. L. W. Anderson, D.R. Krathwohl, and others presented a revision of Bloom's taxonomy of educational objectives in 2001 to re-establish the relevance of the ideas in Handbook (1956) and to incorporate new knowledge and thought produced since 1956. The revised Bloom's Taxonomy of cognitive domain was two-dimensional in contrast to the single dimension of the original taxonomy. The suggested two dimensions are cognitive process and knowledge. The cognitive process dimension contains six categories: *Remember, Understand, Apply, Analyze, Evaluate*, and *Create*. These cognitive processes are organized hierarchically as per cognitive complexity. For example, the process Apply is at higher cognitive complexity than Understand, which means Apply cognitive activities are likely to involve cognitive activities belonging to Understand and Remember cognitive levels. The knowledge dimension contains four categories: Factual, Conceptual, Procedural, and Metacognitive. The two-dimensional nature of the Revised Taxonomy allows a more natural expression of an outcome statement.

> *Revised Bloom's Taxonomy is two-dimensional with six cognitive processes and four knowledge categories*

A typical outcome statement has some subject matter content (a noun or noun phrase) and a description of what is to be done with or to that content (a verb or verb phrase). Consider the statement: State Maxwell's field equations.

- Maxwell's field equations: Subject matter content (Knowledge category)
- State: What is to be done with or to that content - Recall (Cognitive Process)

There exist several other taxonomies: SOLO, Fink, Gagne, and Marzano & Kendall. All taxonomies attempt to structure the processes involved in learning based on observations of learning behaviors and the limited understanding of how the brain functions. Our focus will be on Revised Bloom's Taxonomy and Revised Bloom-Vincenti Taxonomy which includes additional categories of knowledge specific to Engineering.

3.2 Cognitive Processes

Cognitive processes are attention, perception, comprehension, calculation, judgment, storing in memory, reasoning, retrieval from memory, learning, planning, problem-solving, self-monitoring, and speech formation. 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 demonstrate cognitive learning. This domain on the acquisition and use of knowledge is predominant in most courses. As per the revised Bloom's taxonomy, the taxonomy of cognitive processes involved in learning are

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

There are several subprocesses associated with each one of these cognitive processes. One must use the words representing the six categories of cognitive processes as defined by Bloom. Let us understand the cognitive processes.

3.2.1 Remember

The process category is Remember when the objective of instruction is to promote retention of the presented material in much the same form as it was presented. Remembering involves retrieving relevant knowledge from long-term memory. The two associative cognitive processes are **recognizing** and **recalling**.

Remember cognitive process has two processes: Recognize and Recall

The student is given recognition or recall-task under conditions very similar to those in which he or she learned the material to assess student learning in the simplest process category. Little, if any, extension beyond those conditions is expected. If, for example, a student has learned the symbols for various logical functions, then the test of remembering could involve requesting the student to match the logical functions given in one list with symbols shown in a second list. The test for recall could include asking the student to provide the symbols for specified logical functions.

Remembering knowledge is essential for meaningful learning and problem-solving. However, when teachers focus on meaningful learning, remembering knowledge is integrated within the more significant task of constructing new knowledge or solving new problems.

Recognizing involves retrieving relevant knowledge from long-term memory to compare it with the presented information. In recognizing, the student searches long-term memory for a piece of identical or very similar information to the given information. Three main methods of presenting a recognition task for the purpose of assessment are verification, matching, and forced choice.

Recalling (retrieving) involves retrieving relevant knowledge from long-term memory when given a prompt to do so. The prompt is often a question. In recalling, a student searches a long-term memory for a piece of information and brings that piece of information to working memory where it can be processed.

Remembering, therefore, is retrieving relevant knowledge from long-term memory. The relevant knowledge may be factual, conceptual, procedural, or some combination of these. Remembering knowledge is essential for meaningful learning and problem-solving. Some action verbs associated with remembering activity include *recognize, recall, list, tell, locate, write, find, mention, state, draw, label, define, name, describe, prove a theorem.*

Some generic questions related to **Remember** activities are:

- What happened after...?
- How many...?
- Who was it that...?
- Can you name the...?
- Describe what happened at...?
- Who spoke to...?
- What is the meaning of...?

3.2.2 Understand

Students are said to understand when they can construct meaning from instructional messages, including oral, written, graphic communications. These messages are presented to students during lectures, in books, or on computer monitors. Examples of instructional messages include laboratory demonstrations, observations during field trips and role-playing sessions, results of computer simulations, and verbal, pictorial, and symbolic representations on paper. Students understand when they build connections between the new knowledge to be gained and their prior knowledge. Since concepts are building blocks for these schemas and frameworks, conceptual knowledge provides a basis for understanding. Cognitive processes in this category of Understand and the associated action verbs are:

Understand cognitive process has seven sub-processes: Interpret, Exemplify, Classify, Summarize, Infer, Compare, and Explain

- Interpret: Translate, paraphrase, represent and clarify
- Exemplify: Illustrate and instantiate
- Classify: Categorize and subsume
- Summarize: Generalize and abstract
- Infer: Find a pattern
- Compare: Contrast, match, and map
- Explain: Construct a model

The word “Understand” is to be used in the context of RevisedBloom taxonomy to mean strictly to represent these seven sub-processes.

Interpretingoccurs when a student converts information from one representative form to another. Interpreting may involve converting words to words (paraphrasing), pictures to words, words to pictures, numbers to words, words to numbers, and the like. Alternative terms for interpreting are translating, paraphrasing, representing, and clarifying.

Exemplifyingoccurs when a student gives a specific example or instance of a general concept or principle. Exemplifying involves identifying the general concept or principle's defining features and using these features to select or construct a specific instance. Alternative terms are illustrating and instantiating.

Classifying occurs when a student recognizes that something belongs to a specific category (concept or principle). Classifying involves detecting relevant features or patterns that fit both the instance and concept or principle. Classifying is a complementary process to exemplifying. Alternative terms for classifying are categorizing and subsuming.

Summarizingoccurs when a student suggests a single statement that represents presented information or abstracts a general theme. Summarizing involves constructing a representation of information, such as the meaning of a scene in a play, and abstracting a summary from it, such as determining a theme or main points. Alternate terms are generalizing and abstracting.

Inferring involves finding a pattern within a series of examples or instances. Inferring occurs when a student abstracts a concept or principle that accounts for a set of examples or instances by encoding the relevant features or each instance and, most important, by noting relationships among them. A student can distinguish a pattern in the series of numbers 1, 2, 3, 5, 8, 13, 21, …. The process of inferring involves making comparisons among instances within the context of the entire set. A related process uses the pattern to create a new instance (e.g., the next number on the series is 34, the sum of 21 and 13). It is an example of executing, which is a cognitive process associated with Apply. Inferring and executing are often used together on cognitive tasks.

Comparing involves detecting similarities and differences between two or more objects, events, ideas, problems, or situations, such as determining how a 'well-known event' is like or unlike a less familiar event. Comparing includes finding a one-to-one correspondence between elements and patterns in one object, event, or idea and those in another object, event, or idea. When used in conjunction with inferring (e.g., first, abstracting a rule from the more familiar situation) and implementing (e.g., second, applying the rule to the less familiar situation), comparing can contribute to reasoning by analogy. Alternative terms are contrasting, matching, and mapping.

Explaining occurs when a student constructs and uses a cause-and-effect model of a system. The model may be derived from formal theory (as is often the case of the natural sciences) or experience. A complete explanation involves constructing a cause-and-effect model, including each significant part in the system or each major event in the chain, and using the model to determine how a change in one part of the system or one "link" in chain influences another section or the whole. An alternate term of explaining is constructing a model.

Some sample **Understand** activities are:

- Explain why in a DC machine flux per pole decreases with an increase in load.
- Compare memory mapped I/O and peripheral mapped I/O techniques.
- Explain the use of the virtual base class.
- Explain slip and creep phenomena in belt drives.
- Compare the working of impulse and reaction steam turbine.
- Under what conditions do you choose the Inverse Chebyshev filter over the Chebyshev filter?

Some generic questions related to **Understand** activities are:

- Provide an example of... .?
- What was the main idea expressed in... .?
- Write in your own words...?
- Write a brief outline...?
- What do you think could happen next...?
- Who do you think...?
- Distinguish between...?
- What differences exist between...?
- Provide an example of what you mean...?

3.2.3 Apply

Apply involves using procedures to perform exercises or solve problems. Thus, apply is closely linked with *Procedural Knowledge.* An exercise is a task for which the student already knows the proper procedure to use, so the student has developed a routinized approach to it. A problem is a task for which the student initially does not know what procedure to use, so the student must locate a procedure to solve the problem. The apply process consists of two cognitive processes: *executing* – when the task is an exercise (familiar) – and *implementing* – when the task is a problem (unfamiliar).

Executeoccurs when a student routinely carries out a procedure when confronted with a familiar task (exercise). The familiarity of the situation often provides clues to guide the choice of the appropriate procedure to use. Executing is more frequently associated with the use of *skills* and *algorithms* than with the *techniques* and *methods*. Skills and algorithms have two qualities that make them particularly amenable to executing. First, 'executing' consists of a sequence of steps followed in a *fixed order*. Second, when you perform all the steps correctly, the result is a predetermined answer. An alternative term for *executing* is *carrying out*.

Implement occurs when a student selects and uses a procedure to perform an unfamiliar task. Because selection is required, the student must understand the type of problem encountered and the range of available procedures. Thus, implementing is used in conjunction with other cognitive process categories, such as *Understand* and *Create*. Because the student faces an unfamiliar problem, he or she does not immediately know which of the available procedures to use. Furthermore, no single procedure may be a "perfect fit" for the problem; some procedures may require modifications. Implementing is more frequently associated with the use of techniques and methods than with skills and algorithms. Techniques and methods have two qualities that make them particularly amenable to implementation. First, the procedure may be more like a "flow chart" than a fixed sequence; that is, the procedure may have "decision points" built into it. Second, there often is no single, fixed, and expected answer when the procedure is applied correctly. The notion of no 'single and fixed' solution is especially applicable to objectives that call for applying *conceptual knowledge* such as theories, models, and structures where no known procedures seem to exist. An alternative term for *implementing* is *using*.

Apply cognitive process has two sub-processes: Execute and Implement

Some sample **Apply** activities are:

- The primary and secondary windings of a 40KVA, 6600 V/250 V single-phase transformer has resistance 10W and 0.02W, respectively. The total leakage reactance is 35W, as referred to as the primary winding. Find full-load voltage regulation at a lagging power factor of 0.8.
- Design a notch filter to provide attenuation better than 20 dB to signals in the frequency band of 49 Hz to 51 Hz and a gain of 6 dB to signals in the passband.
- Calculate the time taken by a 200-ton motor coach to attain a speed of 50 kmph when it starts on an upgradient of 30 in 1000. The motorcoach has four motors, with each motor developing 6000 Nm torque during acceleration when it starts from rest and has a gear ratio of 4. The gear transmission efficiency 90%, wheel radius is 45 cm, train resistance 50 N/ton, and rotational inertia10%.
- A 1000 cc core cutter weighing 946.80 gm was used to determine the in-situ unit weight of an embankment. The weight of the core cutter filled with soil is 2770.60 gm. Water content was 10.45%, and the specific gravity of the solid is 2.65. Determine bulk unit weight, dry unit weight, void ratio, and degree of saturation.

3.2.4 Analyze

Analyse involves breaking material into its constituent parts and determining how the parts are related to one another and an overall structure. This process category includes the cognitive processes of differentiating (determining the essential and vital pieces of a message), organizing (determining how the parts of the message are organized), and attributing (identifying the purpose of the message). Learning to maybe as an end itself. Educationally it is considered as an extension of Understanding or as a prelude to Evaluating and Creating. A teacher may wish to develop in his/her students the ability to:

- Distinguish fact from opinion (or reality from fantasy)
- Connect conclusions with supporting statements
- Distinguish relevant from extraneous material
- Determine how ideas are related to one another
- Ascertain the unstated assumptions involved in what is said
- Find evidence in support of the author's purposes

The use of the verb 'Analyze' in engineering is a bit tricky despite its extensive usage. Many a time, it is used to imply some "apply" activity.

The processes of Understanding, Analysing, and Evaluating are interrelated and often used iteratively in performing cognitive tasks. At the same time, however, it is important to maintain them as separate process categories. A person who understands communication may not be able to do it well. Similarly, someone who is skilful in analyzing a communication may evaluate it poorly.

Differentiating involves distinguishing the parts of a whole structure in terms of their relevance or importance. *Differentiating* occurs when a student discriminates relevant from irrelevant information, important from unimportant, and then attends to relevant and essential information. *Differentiating* differs from *comparing* in using the broader context to determine what is appropriate and crucial. In 'comparing,' all factors are equal irrespective of their relevance and importance. Alternate terms for *differentiating* are *discriminating*, *selecting*, *distinguishing*, and *focusing*.

Organizing involves identifying the elements of communication or situation and recognizing how they fit together into a coherent structure. In organizing, a student builds systematic and logical connections among the pieces to the presented information. *Organizing* usually occurs in conjunction with *differentiating*. The student first identifies the relevant or essential elements and then determines the overall structure within which the components fit. *Organizing* can also occur in conjunction with *attributing*, in which the focus is on identifying the author's intention or point of view. Alternative terms for *organizing* are *structuring*, *integrating*, *findingcoherence*, *outlining*, and *parsing*.

Attributing occurs when a student ascertains the point of view, biases, values, or intentions underlying communications. *Attributing* involves a process of deconstruction, in which a student determines the author's intentions of the presented material. In contrast to interpreting, in which the student seeks to *understand* the meaning of the submitted content, *attributing* involves extension beyond basic *understanding* to infer the intention or point of view underlying the submitted material. An alternative term is *deconstructing*.

Analyze cognitive process has three sub-processes: Differentiate, Organize and Attribute

Some sample **Analyze** activities are:

- refining generalizations and avoiding oversimplifications
- developing one's perspective: creating or exploring beliefs, arguments, or theories
- clarifying issues, conclusions, or beliefs
- developing criteria for evaluation: defining values and standards
- evaluating the credibility of sources of information
- questioning deeply: raising and pursuing root or significant questions
- clarifying arguments, interpretations, beliefs, or theories
- reading critically: clarifying or critiquing texts
- examining or evaluating assumptions
- distinguishing relevant from irrelevant facts
- making plausible inferences, predictions, or interpretations
- giving reasons and evaluating evidence and alleged facts
- recognizing contradictions
- exploring implications and consequences

Some generic questions related to **Analyze** activities are:

- What is the theme . . ..?
- What evidence can you find . . .?
- What motive is there . . .?
- How … is related to . . .?

3.2.5 Evaluate

Evaluate is defined as making judgments based on criteria and standards. The criteria most often used are quality, effectiveness, efficiency, and consistency. Students or the tester will identify criteria. The standards may be quantitative or qualitative. Evaluating includes the cognitive processes of checking (judgments about internal consistency) and critiquing (judgments based on external criteria). However, all judgments are evaluative. Most cognitive processes require some form of judgment. What most differentiates Evaluate from other students' judgments is the use of standards of performance with clearly defined criteria. Is this machine or software working as efficiently as it should be? Is this method the best way to achieve the goal? Is this approach the most cost-effective than other approaches?

Checking involves testing for internal inconsistencies or fallacies in operation or a product. For example, *checking* occurs when a student tests whether a conclusion follows its premises, whether data support or disconfirm a hypothesis, or whether presented material contains parts that contradict one another. When combined with *planning* (a cognitive process in the category *Create*) and *implementing* (a cognitive process in the category *Apply*), checking involves determining how well the plan is working. Alternative terms for *checking* are testing, detecting, monitoring, and coordinating.

Critiquing involves judging a product or operation based on externally imposed criteria and standards. *Critiquing* lies at the core of what has been called critical thinking. An example of *critiquing* is judging the merits of a solution to the problem of acid rain in terms of likely effectiveness and its associated costs. An alternate name is judging.

Evaluate cognitive process has two sub-processes: Check and Critique

Some sample **Evaluate** activities are:

- Select the factor among the following that has maximum impact on climate change
    - Carbonated soft drinks like Pepsi and Coke
    - Automobiles
    - Cell phones
    - Fast food
- What would you recommend . . .?
- What would you cite to defend the actions . . .?
- What choice you would have made . . .?
- How would you rate the . . .?

3.2.6 Create

Create involves putting elements together to form a coherent or functional whole. Objectives classified as Create have students make a new product by mentally reorganizing some elements or parts into a pattern or structure not-present before. Although Create requires creative thinking on the student's part, this is not entirely free creative expression unconstrained by the demands of the learning task or situations. To some persons, creativity is the production of superior products, often due to some special skills. 'Create,' as used here, includes objectives that call for unique production, also refers to objectives calling for production that all students can and will do. If nothing else, in meeting these objectives, many students will create in the sense of producing their synthesis of information or materials to form a new whole, as in a circuit, a software unit, a mechanism, a structure, and so on.

Although the process categories of Understand, Apply, and Analyse may involve detecting relationships among the presented elements, Create is different because it also consists of constructing an original product. Unlike create, the other categories include working with a given set of elements that are part of a given whole; that is, they are part of a larger structure the student is trying to understand. In creating, on the other hand, the student must draw upon elements from many sources and put them together into a novel structure or pattern relative to his or her prior knowledge. Create results in a new product, which is more than the student's beginning materials. A task that requires Create is likely to require aspects of each of the earlier cognitive process categories to some extent, but not necessarily in a specific order.

The creative process is of three phases: problem representation, in which a student attempts to understand the task and generate possible solutions; solution planning, in which a student examines the possibilities and devices a workable plan; and solution execution, in which a student successfully carries out the plan. Therefore, the creative process can be thought of as starting with a divergent phase in which a variety of possible solutions are considered as the student attempts to understand the task (generating). This phase is followed by a convergent phase, in which the student devises a solution method and turns it into a plan of action (planning). Finally, the plan is executed as the student constructs the solution (producing). It is not surprising that the Create is associated with three cognitive processes: generating, planning, and producing.

Generating involves representing the problem and arriving at alternatives or hypotheses that meet specific criteria. Often, the way a problem is initially described suggests possible solutions; however, redefining or coming up with a new representation of the problem may suggest different solutions. When generating transcends the boundaries or constraints or prior knowledge and existing theories, it involves divergent thinking and forms the core of creative thinking. Generating is used in a restricted sense here. Understand also requires generative processes included in translating, exemplifying, summarizing, inferring, classifying, comparing, and explaining. However, the goal of Understanding is most often convergent (that is, to arrive at a single meaning). In contrast, the purpose of generating within Create is divergent (that is, to arrive at various possibilities). An alternative term for generating is hypothesizing.

Planning involves devising a solution method that meets a problem's criteria, developing a plan for solving the problem. Planning stops short of carrying out the steps to create a real solution for a given problem. In planning, a student may establish sub-goals or break a task into subtasks to be performed when solving the problem. An alternative term is designing.

Producing involves carrying out a plan for solving a given problem that meets specifications.

Created cognitive process has three sub-processes: Generate, Plan and Produce

Objectives within the category Create may or may not include originality or uniqueness as of the specifications. So, it is with producing objectives. Producing can require the coordination of the four types of knowledge. An alternative term is construction.

Some sample **Create** activities are:

- Specify and design a cost-effective FM receiver.
- Specify and design a cost-effective 3D printing machine that can serve the purpose of developing and producing small plastic parts.
- Design a reliable drinking water supply system for a community of 10000 people with groundwater sources.

3.2.7 Critical Thinking

Critical thinking involves cognitive processes including 1) identifying the assumptions that frame our thinking and determine our actions, 2) checking out the degree to which these assumptions are accurate and valid, 3) looking at our ideas and decisions (intellectual, organizational, and personal) from several different perspectives, and 4) based on all this taking informed actions. The basic typology of the assumptions that critical thinking unearths and scrutinizes includes paradigmatic, prescriptive, and causal (Brookfield 2012). Paradigmatic assumptions are the hardest of all assumptions to uncover. They are the structuring assumptions we use to order the world into fundamental categories. Usually, we do not even recognize them as assumptions, even after being pointed out to us. Prescriptive assumptions are assumptions about what we think ought to be happening in each situation. They are the assumptions that surface as we examine how we think, we/others should behave, what good learning and educational processes should look like, and what obligations students and teachers owe to each other. Inevitably they are grounded in, and extensions of, our paradigmatic assumptions. Causal assumptions are assumptions about how different parts of the world work and the conditions under which they can be changed. Of all the assumptions we hold, causal ones are the easiest to uncover. Approximately 80% of assumptions covered in any conversation, class, course, or workshop will be causal. Causal assumptions are usually stated in two ways: when those assumptions govern future behavior, and the second ones are stated retroactively or historically. Assumptions are rarely right or wrong; they are contextually appropriate.

There are five distinct intellectual traditions shaping understandings of critical thinking.

1. Analytic philosophy and Logic: Detecting Language Tricks
2. Natural Sciences: The Hypothetico-Deductive Method
3. Pragmatism: The Experimental Pursuit of Beautiful Consequences

4. Psychoanalysis: Living an Integrated, Authentic Life
5. Critical theory: Speaking Truth to Power

These traditions are distinct but are not mutually exclusive.

> *Critical thinking unearths and scrutinizes paradigmatic, prescriptive, and causal assumptions.* Revised-Bloom's taxonomy addresses critical thinking through its core cognitive activities and Analyze and Evaluate

We do critical thinking to take informed actions - actions that are grounded in evidence, can be explained to others, and stand a good chance of achieving the results we desire.Revised-Bloom taxonomy addresses critical thinking through its core cognitive activities and Analyze and Evaluate.

3.2.8 Problem Solving

The problem-solving process consists of

- Identification of the problem (Analyse)
- Explore and develop alternative solutions (Create)
- Select the best alternative (Evaluate)
- Implement (build and test the selected solution) (Apply)
- Evaluate the result (Evaluate)

The problem-solving process, therefore, involves some or all the Revised-Bloom cognitive processes. One proposed taxonomy of Problem Solving

- Routines (Apply)
- Diagnosis (Selecting a method: Apply and Analyse)
- Strategy (Order of using methods: Analyse and Evaluate)
- Interpretation (Multiple higher cognitive levels)
- Generation (Multiple higher cognitive levels)

Revised-Bloom taxonomy subsumes Critical Thinking and Problem-Solving processes. The classification of cognitive processes proposed by Revised-Bloom, or any other taxonomy of cognitive processes, should only be considered approximate. For example, it is difficult to draw a line between Understanding and Analysis. According to some neurologists, Revised-Bloom taxonomy appears to be not in contradiction with the processes taking place in the brain.

The analysis of cognitive processes presented here has implications for both teaching and assessing. On the teaching side, two of the cognitive processes help to promote retention of learning, whereas 17 of them help to foster the transfer of learning. Thus, when the goal of instruction is to facilitate the transfer, objectives should include the cognitive processes associated with Understand, Apply, Analyse, Evaluate, and Create. On the assessment side, the analysis of cognitive processes is intended to help broaden their assessment of learning. When instruction is to promote transfer, assessment tasks should tap cognitive processes that go beyond remembering.

The Revised Bloom's taxonomy subsumes critical Thinking and Problem-Solving processes. The classification of cognitive processes, as proposed by Revised Bloom's, or any other taxonomy of cognitive processes, should only be considered approximate. For example, it is difficult to draw a line between Understanding and Analysis. According to some neurologists, the Revised Bloom's taxonomy appears to be not in contradiction with the processes taking place in the brain.

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CHAPTER 4

Categories of Knowledge

4.1 Introduction

While the word 'knowledge' is extensively used by all, there is no single agreed definition of 'knowledge' at present, nor any prospect of one. Knowledge is a term that has been actively and continually defined. Knowledge is a complex of several related ideas. Consider some of the definitions.

Knowledge is relationships, facts, assumptions, heuristics, and models derived through the formal and informal analysis or interpretation of data. (Information Society Technologies http://cordis.europa.eu/ist/ka1/ administrations/publications/glossary.htm).

Knowledge is defined as remembering previously learned material. This may involve the recall of specific facts or complete theories, but all that is required is the rote memory of the appropriate information. Knowledge represents the lowest and most basic level of learning. www.drdan.org/Hnadout%2017.htm

Knowledge is the internalization of information, data, and experience
home.earthlink.net/~ddstuhlman/defin1.htm.

Knowledge is the psychological result of the perception of learning and reasoning
http://wordnetweb.princeton.edu/perl/webwn?s=knowledge.

Knowledge is accumulated external and explicit information belonging to the community, being leveraged by tacit intrinsic insights that originate within individuals who then may act alone or cooperatively to control or integrate with their environment.

http://www.pacrimcross.com/kmguidelines/ defknow.html.

Knowledge is defined (Oxford English Dictionary) variously as expertise and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject what is known in a field; facts and information awareness or familiarity gained by experience of a fact or situation

A branch of philosophy, called 'epistemology**,**' is dedicated to the study of knowledge, and its sources, varieties, and limits. In any branch of philosophy, there are at least two competing views. In epistemology, one view referred to as 'empiricism**,**' holds that knowledge is derived from experience, whereas 'apriorism' considers that knowledge is innate. The extreme form of empiricism is referred to as 'positivism' or 'logical positivism.' It holds that nothing is innate and that only that which can be measured is worth worrying about. The extreme form of apriorism denies the very idea of knowledge existing outside the individual mind. The conventional attitude adopted by non-philosophers is a kind of truce between the two extremes.

The Second half of the twentieth century has witnessed many new turns in the epistemic scenario, the latest among which is a turn towards situated knowledge/cognition. In stark contrast to the traditional epistemology where knowledge was and still is construed as individual, rational, abstract, a perspectival, and value-neutral situated epistemology upholds knowledge to be social, not insulated from emotion, concrete, perspectival and value-endowed. More specifically, the concept of situated cognition is a cluster-concept, and its degree of situatedness depends on how many traits of 'situatedness' have been reflected in a piece of cognition. The said cluster includes three theses: (a) cognition depends not just on the mind/brain but also on the body (the embodiment thesis), (b) cognitive activities routinely exploit structures of the natural and social environment (the embedding thesis), and (c) the boundaries of cognition extend beyond the boundaries of an individual organism (the extension thesis).

The perspective of knowledge, as considered here, is based on the current perspectives in cognitive science and cognitive psychology on knowledge presentation. We do not adhere to a simple behaviorist view that knowledge is best represented as an accumulation of association between stimuli and responses or merely a quantitative increase in bits of information. Instead, our perspective reflects the idea that knowledge is organized and structured by the learner in line with a rationalist-constructivist tradition. Based on cognitive science research on the development of expertise, expert thinking, and problem-solving, our perspective is that knowledge is domain-specific and contextualized. Our understanding of knowledge should reflect this domain specificity and the role that social experiences and context play in the construction and development of knowledge.

4.2 Types of Knowledge in all Disciplines

There are many distinct types of knowledge, and even more terms used to describe them. Some of the terms are conceptual knowledge, conditional knowledge, content knowledge, declarative knowledge, disciplinary knowledge, discourse knowledge, domain knowledge, episodic knowledge, explicit knowledge, factual knowledge, metacognitive knowledge, prior knowledge, procedural knowledge, semantic knowledge, situational knowledge, sociocultural knowledge, strategic knowledge, and tacit knowledge. Some of the different terms signify essential differences among the varieties of knowledge, whereas others are different labels for the same knowledge category. Considering several constraints to categorization and the need for simplicity and ease of use, we propose four general types of knowledge (Anderson et al., 2001) relevant across all disciplines:

- Factual Knowledge
- Conceptual Knowledge
- Procedural Knowledge
- Metacognitive Knowledge

Factual knowledge refers to specific content elements such as terms and facts (bits of information). Conceptual knowledge refers to more general concepts, principles, models, or theories. Procedural knowledge is the "knowledge of how" to do something. The "something" might range from completing routine exercises to solving novel problems. Current cognitive and social constructivist models of learning emphasize ideas such as consciousness, awareness, self-reflection, self-regulation, and thinking about and controlling one's thinking and learning, which were excluded by behaviorist psychology models. Because these activities focus on cognition itself, the prefix meta is added to reflect that metacognition is 'about' or 'above' cognition. Both cognitive and constructivist models agree on the importance of facilitating students' thinking about their thinking. Here we define "metacognitive knowledge" as "knowledge about cognition." Learners can activate the relevant situational, conditional, or cultural knowledge for solving a problem in a specific context.

These four categories of knowledge apply to all disciplines, but do not constitute a complete set. There are categories of knowledge specific to Engineering, Social Sciences, Computing, Management, Economics, etc. While categories of knowledge specific to Social Sciences, Computing, Management, and Economics are not enunciated definitively, the categories of knowledge specific to Engineering have been identified (Vincenti 1990).

The four types of knowledge and their sub-types are explored further in the following sections.

4.2.1 Factual Knowledge

Factual knowledge contains the basic elements students must know if they are to be acquainted with the discipline or solve any of the problems in it. The elements are usually symbols associated with some concrete referents, or "strings of symbols" that convey essential information. Factual Knowledge exists at a low level of abstraction. As our knowledge increases in all fields of inquiry, even experts in these fields have difficulty keeping up with all the new elements. Consequently, some selection for educational purposes is always required. The two subtypes of Factual Knowledge are knowledge of terminology and knowledge of specific details and elements.

Factual knowledge refers to specific content elements such as terms and facts (bits of information).

Knowledge of terminology includes specific verbal and nonverbal labels and symbols (e.g., words, numerals, signs, pictures). Each subject matter contains many labels and symbols, both verbal and nonverbal, that have referents. They are the basic language of the discipline – shorthand used by experts to express what they know. The novice learner must be cognizant of these labels and symbols and learn the accepted referents that are attached to them. Some examples of knowledge of terminology are

- Knowledge of the alphabet and numbers
- Knowledge of engineering or technical terms

- Knowledge of physical and chemical constants
- Knowledge of mathematical and graphic representations
- Knowledge of specific details and elements refers to knowledge of events, locations, people, dates, sources of information, and the like.

It may include exact and specific information, such as the exact date of an event or the exact magnitude of a phenomenon, which could be descriptive or prescriptive. It may also include approximate information, such as a period in which an event occurred or the general order of magnitude of the phenomenon. Specific facts are those that can be isolated as separate, discrete elements in contrast to those that can be known only in a broader context.

Knowledge of specific details and elements: The facts of a given subject belong to this category. However, the tremendous number of particular facts forces educators (curriculum specialists, textbook authors, and teachers) to make choices about what is basic and secondary importance or importance primarily to experts.

Some examples of **knowledge of specific details and elements** are:

- Knowledge of products, companies, and major stakeholders related to computing
- Knowledge of notable events people in the evolution of computing
- Knowledge of prominent features of several types of computers
- Knowledge of currently used semiconductor devices and technologies used for fabricating them
- Knowledge of performance characteristics of commercially available optical microscopes

4.2.2 Conceptual Knowledge

A concept denotes all the entities, phenomena, and/or relations in each category or class by using definitions. Concepts are abstract in that they omit the differences of the things in their extension, treating the members of the extension as identical. Classical concepts are universal in that they apply equally to everything in their extension. Concepts are also the essential elements of propositions, much the same way a word is the essential semantic element of a sentence. Unlike perceptions, which are images of individual objects, concepts cannot be visualized. Because they are not themselves individual perceptions, concepts are discursive and result from reason. Concepts are bearers of meaning, as opposed to agents of meaning. A single concept can be expressed in any number of languages. The concept of DOG can be expressed as a dog in English, Hund in German, as Nayi in Kannada, and Kuttha in Hindi. The fact that concepts are, in some sense, independent of language makes translation possible - words in various languages have identical meanings because they express the same concept.

Conceptual knowledge includes knowledge of categories and classifications, and the relationships between and among them – more complex, organized knowledge forms. Conceptual knowledge includes schemas, mental models, or implicit or explicit theories in different cognitive psychological models. These schemas, models, and theories represent the knowledge an individual has about how a subject matter is organized and structured, how the various parts or bits of information are interconnected and interrelated in a more systematic manner, and how these parts function together. For example, the mental model of how a computer works may include ideas about how information can be represented in binary form, Boolean algebra, logical expressions, registers, instructions, control unit, ALU, primary memory, secondary memory, storage media, display of information, keyboards, printers, etc. This type of conceptual knowledge might be one aspect of what is termed "disciplinary knowledge."

Conceptual knowledge includes knowledge of classifications and categories, knowledge of principles and generalization, and knowledge of theories, models, and structures.

Conceptual knowledge includes three subtypes: knowledge of classifications and categories, knowledge of principles and generalization, and knowledge of theories, models, and structures. Classification and categories form the basis for principles and generalizations. These, in turn, form the basis for theories, models, and structures. These three subtypes should capture a great deal of the knowledge that is generated within different disciplines.

Knowledge of Classification and Categories includes specific categories, classes, divisions, and arrangements that are used in different subject matters. This type of knowledge is more general and often more abstract than terminology and specific facts. Each subject matter has a set of categories that are used to discover new elements and deal with them once they are discovered. Classification and categories differ from terminology and facts in that they form the connecting links between and among specific elements. When one is concerned with realizing a logic expression, the major categories include 'binary variables' 'logic functions,' 'truth-tables,' 'hardware logic units,' 'assertion levels,' etc.

Sometimes it is challenging to distinguish knowledge of classifications and categories from factual knowledge. Primary classifications and categories can be placed into larger, more comprehensive classifications and categories. For example, binary, hex, octal, and decimal systems can be placed into number systems.

Knowledge of classifications and categories is an essential aspect of developing expertise in an academic discipline. Proper classification of information and experience into appropriate categories is a classic sign of learning and development. Some examples of knowledge of classification and categories are

- Knowledge of number systems

- Knowledge different electronic packages

Principles and Generalizations are composed of classifications and categories. Principles and generalizations tend to dominate an academic discipline and are used to study phenomena or solve problems in the discipline. These include abstractions that summarize observations of phenomena and have the highest value in describing, predicting, explaining, or determining the most appropriate and relevant action or direction to be taken. Principles and generalizations bring together many specific facts and events, describe the processes and interrelationships among these specific details (thus forming classifications and categories, and describe processes and interrelationships and among the classifications and categories). Principles and generalizations enable us to organize the whole in an economical and coherent manner.Examples of knowledge of principles and generalizations are

- Knowledge of fundamental laws of physics
- Knowledge of Boolean algebra
- Knowledge of the principles that govern arithmetic operations

Knowledge of Theories, Models, and Structures include different paradigms and epistemologies that disciplines have for structuring inquiry. Students should know these separate ways of conceptualizing and organizing subject matter and areas of research within the subject matter.

For example, the relevant operating characteristics of electrical and electronic devices are described through currents and voltages as time functions at appropriately selected points or point pairs. An expert in a discipline knows not only the different disciplinary theories, models, and structures but also their relative strengths and weaknesses and can think “within” as one of them as well as “outside” any of them. Examples of knowledge of theories, models, and structures are

- Knowledge of field theory
- Knowledge of the theory of analog signal filtering
- Knowledge theory of digital signal processing
- Knowledge of systems view of organizations

4.2.3 Procedural Knowledge

Procedural knowledge is the “knowledge of how” to do something. The “something” might range from completing routine exercises to solving novel problems. Procedural knowledge often takes the form of a series or sequence of steps to be followed. It includes knowledge of skills, algorithms, techniques, and methods, collectively known as procedures. Procedural knowledge also includes knowledge of the criteria used to determine when to use the procedures.

Procedural knowledge is specific or germane to a subject matter or an academic discipline. In mathematics, for example, there are algorithms to find the local minimum value of a function to determine the determinant of a square matrix, etc. In digital systems, there are methods to prepare a truth-table from a logic expression, to minimize a given logic expression, to do state assignment, etc. The subcategories of procedural knowledge are:

- Knowledge of subject-specific skills and algorithms
- Knowledge of subject-specific techniques and methods
- Knowledge of criteria for determining when to use appropriate procedures

Knowledge of subject-specific skills and algorithms can be expressed as a series or a sequence of steps. Sometimes the steps are followed in a fixed order; at other times, decisions must be made which step to perform next. The result is considered fixed in this type of knowledge.Examples of this category of knowledge include

- Knowledge of algorithms used with mathematics exercises
- Knowledge of algorithms for minimizing logic expressions
- Knowledge of pattern-search algorithms in Artificial Intelligence

Knowledge of subject-specific techniques and methods includes knowledge that is mostly the result of consensus, agreement, or disciplinary norms rather than knowledge that is more directly an outcome of observation, experimentation, or discovery. This subtype of knowledge reflects how experts in the field or discipline think and solve problems. Examples of this category of knowledge include

- Knowledge of methods of management research
- Knowledge of system dynamics methods to model complex socio-technical systems

Knowledge of criteria for determining when to use appropriate procedures involves knowing the ways they have been used in the past. Systematization is used by subject matter experts as they solve problems in their field. Experts know when and where to apply their knowledge. They have criteria that help them make decisions about when and where to use diverse types of subject-specific procedural-knowledge. Their knowledge is "conditionalized" because they know the conditions under which a given procedure is to be applied. Initially, these criteria are likely to appear complex and abstract to students; they acquire meaning related to concrete situations and problems. Examples of this category of knowledge include

Procedural knowledge is the "knowledge of how" to do something and knowledge of the criteria used to determine when to use the procedures.

- Knowledge of the criteria for determining whether to use time-domain methods or frequency domain methods in analyzing a given electrical circuit.
- Knowledge of the criteria for determining which statistical procedure to use with the data collected in an experiment

- Knowledge of the criteria for determining which transformation is to be applied in a signal processing problem

4.2.4 Metacognitive Knowledge

Metacognitive knowledge is knowledge about cognition in general and awareness of and knowledge about one's cognition. Regardless of their theoretical perspective, researchers agree that with development, students will become more aware of their thinking and more knowledgeable about cognition in general, and as they act on this awareness, hey will learn better (Bransford, Brown, and Cocking, 1999). The labels for this general developmental trend vary from theory to theory but include metacognitive knowledge, metacognitive awareness, self-awareness, self-reflection, and self-regulation. An essential distinction in the field is between knowledge of cognition and the monitoring, control, and regulation of cognition. Flavell (1979) suggested that metacognition included knowledge of strategy, task, and person variables. These are categorized here as

- Strategic knowledge
- Knowledge about cognitive tasks
- Self-knowledge

Strategic knowledge is knowledge of the general strategies for learning, thinking, and problem-solving. The strategies in this subtype can be used across many different tasks and subject matters. This subtype includes knowledge of the variety of strategies that students might use to memorize material, extract meaning from text, or comprehend what they hear in classrooms or read in books and other course materials. These learning strategies can be grouped into three general categories: rehearsal, elaboration, and organizational (Weinstein and Mayer, 1986).

Strategic knowledge is knowledge of the general strategies for learning, thinking, and problem-solving.

- Rehearsal strategies involve repeating words or terms to be recalled over and over to oneself; they are not the most effective strategies for deeper levels of learning and comprehension.
- Elaboration strategies include using various mnemonics for memory tasks and techniques such as summarizing, paraphrasing, and selecting the main idea from texts. Elaboration strategies foster deeper processing of the material to be learned and result in better comprehension and learning than rehearsal strategies.
- Organizational strategies include various forms of outlining, drawing "cognitive maps", mind mapping or concept mapping, and note-taking; students transform the material from one form to another. Organizational strategies usually result in better comprehension and learning than do rehearsal strategies.

In addition to these general learning strategies, students can know metacognitive strategies useful in planning, monitoring, and regulating their cognition. Students can eventually use these strategies to plan their cognition (e.g., set sub-goals), monitor their cognition (e.g., ask themselves questions as they read a piece of text, check their answer to a math problem) and regulate their cognition (e.g., re-read something they don't understand, go back and "repair" their calculating mistake in a math problem).

Self-knowledge is knowledge of one's strengths and weaknesses of cognition and learning.

This subtype of knowledge also includes general strategies for problem-solving and thinking. These strategies represent the various general heuristics students can use to solve problems, particularly ill-defined problems that have no definitive solution method. Examples of heuristics are means-ends analysis and working backward from the desired goal state. In addition to problem-solving strategies, there are general strategies for deductive and inductive thinking (including evaluating the validity of different logical statements, avoiding circularity in arguments, making appropriate inferences from various sources of data, and heuristic – making decisions from convenient instead of representative symbols).

Students need to develop self-knowledge and awareness about their motivation.

The third subtype includes knowledge about cognitive tasks, including contextual and conditional knowledge. Different cognitive tasks can be difficult, and may make differential demands on the cognitive system, and may require different cognitive strategies. For example, a recall task is more difficult than a recognition task. As students develop knowledge of different learning and thinking strategies, this knowledge reflects both general strategies and how to use them. Students also need to develop conditional knowledge for these general cognitive strategies; in other words, they need to develop some knowledge about when and why of using these strategies appropriately. All these different strategies may not be appropriate for all situations. The learner must develop some knowledge of different conditions and tasks for which the different strategies are most appropriate. Conditional knowledge refers to knowledge of the situations in which students may use Metacognitive knowledge. If one thinks of strategies as cognitive "tools" that help students construct understanding, then different cognitive tasks require different tools. An important aspect of learning about strategies is the conditional knowledge of when and why to use them appropriately. Another important aspect of conditional knowledge is the local situational and general, conventional, and cultural norms for using different strategies. For example, the strategies used in a classroom learning situation may not be the most appropriate ones to use in a work setting.

Self-knowledge includes knowledge of one's strengths and weaknesses of cognition and learning. One hallmark of experts is that they know when they do not know something, and they then have some general strategies for finding the needed and appropriate information. Self-awareness of the breadth and depth of one's knowledge base is an important aspect of self-knowledge.

Students need to be aware of the several types of general strategies they are likely to rely on in different situations. An awareness that one tends to over-rely on one strategy, when there may be other more adaptive strategies for the task, could lead to a change in strategy use.

In addition to knowledge of one's general cognition, individuals have beliefs about their motivation. Motivation is a complicated and confusing area. A consensus has emerged, however, around general social cognitive models of motivation that propose three sets of motivational beliefs.

Self-efficacy beliefs that are students' judgments of their capability to accomplish a specific taskBeliefs about goals or reasons students have for pursuing a specific task (e.g., learning vs.getting a good grade)Students' perception of their interest (liking) for a task as well their judgments of how important and useful the task is to them

Just as students need to develop self-knowledge and awareness about their knowledge and cognition, they also need to develop self-knowledge and awareness about their motivation. Again, awareness of these different motivational beliefs may enable the learners to monitor and regulate their behavior in learning situations in a more adaptive manner.

Self-knowledge is an essential aspect of Metacognitive knowledge, but the accuracy of self-knowledge is most crucial for learning. The role of the teacher is to help students make an accurate assessment of their self-knowledge and not attempt to inflate students' academic self-esteem.

4.3 Categories of Engineering Knowledge

Engineering knowledge is pursued at great effort and expense in schools of engineering. Many scholars tend to think of it as applied science. Modern engineering is seen as taking over its knowledge from scientists and, by occasionally dramatic, intellectually uninteresting process, using this knowledge to fashion material artefacts. From this standpoint, studying the epistemology of science should automatically subsume the knowledge content of engineering. Engineers know from experience that this view is untrue. In the opinions of many historians, technology and engineering appear not as derivatives from science but autonomous bodies of knowledge, identifiably different from the scientific knowledge they interact with. Engineering has its significant component of thought, though different in its specifics, resembles scientific thought in being creative and constructive; it is not merely routine and deductive as assumed in the applied-science model. In this view, though it may apply science, engineering is different from or entirely applied science.

Treating science and technology (engineering) as separate spheres of knowledge, both human-made, appears to fit the historical record better than treating science as revealed knowledge and technology as a collection of artifacts once constructed by trial and error but now constructed by applying science (Wise 1985). For engineers, in contrast to scientists, knowledge is not an end or their profession's central objective. Instead, it is a means to a many utilitarian ends. G.F.C. Rogers (1983) states: engineering refers to the practice of organizing the design, construction, and operation of any artifice which transforms the physical world around us to meet a recognized need". These terms may be interpreted as:

- Organize - bringing into being, get together or arrange
- Design - plans from which the artifice is built, as in drawings or computer displays
- Construction - production or manufacturing
- Operation - employment of the artifice in meeting the recognized need

Design denotes both the content of a set of plans and the process by which those plans are produced. As a process, design involves a tentative layout of the arrangement and dimensions of the artifice, checking of the candidate device by mathematical analysis or experimental test to see if it does not. Such a procedure usually requires may iterations before finally dimensioned plans can be released for production. Events in doing are also more complicated than the brief outlines suggest. Many difficult trade-offs may be required, calling for decisions based on incomplete or uncertain knowledge. If available knowledge is inadequate, detailed research may have to be undertaken. The process is a complicated and fascinating one that needs more historical analysis than it has received.

Design activity can be considered either a normal design or a radical design. The engineer involved in normal design knows at the outset how the device in question works, what are its customary features, and that it has a reasonable likelihood of accomplishing the desired task if properly designed along such lines. The way a device should be arranged or even its working is mostly unknown in radical design. The designer has never seen such a device before and has no resumption of success. The procedure is to design something that will function well enough to warrant further development. The normal design makes up by far the bulk of day-to-day engineering enterprises.

The knowledge required by normal design and radical design cannot be sharply separated; there are middle levels of novelty where the distinction is difficult to make. Normal design is not routine and deductive and mostly static. Like technology, it is creative and constructive and changes over time, as designers pursue ever more ambitious goals. The changes are incremental instead of essential; the normal design is evolutionary rather than revolutionary, even within such limits, the kinds of knowledge required are enormously diverse and complex. The activities that produce the knowledge, unlike the activity it is intended to support, are also sometimes far from normal and day-to-day. Engineering knowledge reflects the fact that design does not take place for its own sake and in isolation. Artefactual design is a social activity directed at a practical set of goals intended bound up with economic, military, social, personal, and environmental needs, and constraints. These needs and constraints are referred to as “contextual factors” that constitute the artifact's ambiance. In normal design, this ambiance exercises its most significant direct effect at the hierarchy's upper levels, where projects are defined and laid out. At the lower levels of design, though still present, the contextual influence tends to be weaker and less direct; at these levels, knowledge derives from the internal needs of design itself.

Engineering knowledge may be categorized (Vincenti 1990) into:

1. **Fundamental Design Concepts**: Operational principles of the devices. Operational principles also exist for the components within a device.
2. **Criteria and Specifications**: It is necessary to translate the device's qualitative goals into specific, quantitative goals. Design criteria vary widely in perceptibility. Assignment of the values or limits is usually (but not always) a particular design and is best looked upon as part of the design process
3. **Theoretical Tools**: Mathematical tools. Physical principles. Theories are based on scientific principles but motivated by and limited to a technologically important class of phenomena or even to a specific device. An assortment of theories involving some central and ad hoc assumption about phenomena crucial to the problem may be termed phenomenological theories. Quantitative assumptions are introduced for calculative expedience.
4. **Quantitative Data**: Descriptive (physical constants) and prescriptive (how things should be) data
5. **Practical Constraints**: These represent an array of less sharply defined considerations derived from experience in practice, considerations that frequently do not lend themselves to theorizing, tabulation, or programming into a computer.
6. **Design Instrumentalities**: These refer to procedural knowledge. Instrumentalities of the process include the procedures, way of thinking, and judgmental skills by which it is done.

Let us consider some samples of engineering knowledge predominantly from the field of electrical engineering:

Fundamental Design Concepts

1. A device can perform a variety of tasks by incorporating memory into it.
2. A device that has two well-defined states can be used as a memory unit.
3. Stepping movement can be created through the interaction between two salient magnetic fields.

4. An airplane operates by propelling a rigid surface forward through the resisting air, thus producing the upward force required to balance the airplane's weight.
5. By virtue of its shape, an air foil, particularly its sharp trailing edge, generates lift when inclined at an angle to the air stream.
6. By controlling the phase angle of switching and allowing the switching device to get naturally commutated with the ac power supply, it can control the power to any load.
7. A conducting power switching device can be commutated by forcing current in the opposite direction.
8. The efficiency of the power converter can be improved by switching the devices at zero current.

Criteria and Specifications

1. Any power converter should have efficiency above 95%.
2. An SMPS should not source of excessive electromagnetic disturbance.
3. The measurement of instantaneous power should be accurate.
4. The speed control unit for the dc motor should not create excessive harmonic
5. distortion on the power line.
6. The SMPS output should have an output regulation of 0.5%.
7. The speed of the dc motor should be controlled over a speed range of 1 to 300
8. RPM with an accuracy of 0.05%.
9. The phase angle between the voltage and current waveforms should be measured
10. with an accuracy of 0.1 degrees.
11. Specification like overshoot, settling time, time constants, and steady-state error

Theoretical Tools

1. Kirchhoff's laws.
2. Electromagnetic induction.
3. p-n junction theory.
4. p-n-p-n junction switching theory.
5. Theory of operation of MOSFET
6. Laplace transforms.
7. Fourier Transforms.
8. Concepts like force, torque, efficiency, feedback, and feed-forward
9. High-frequency models of transistors.
10. Model for the switching behavior of a power transistor
11. The thermal resistance of the switching devices
12. V-I characteristic of a diode.

Quantitative Data

1. The voltage across the switching device is 0.1 V.

2. Factors of safety.
3. Physical constants like the acceleration of gravity and Plank's constant
4. What does one micron mean when a simply supported beam deflects under load.
5. Properties of substances like failing strength of materials, electrical conductivity, and thermal conductivity
6. The electrical resistance of a human being
7. Engineering standards concerning absolute values and tolerances

Practical Constraints

1. The drilling machine available cannot drill holes larger than 0.5".
2. The PCB should be compatible with the PC motherboard.
3. The legend should be written above the switch on the front panel.
4. The indicator lamp should be above the switch.
5. The clearances must be allowed between physical parts in equipment for tools and hands to reach different parts.
6. The design should be completed within two months.

Design Instrumentalities

1. The top-down approach to the design of a product
2. Phasing of development of a product
3. Structuring of an electronic product.
4. Design walkthroughs.
5. Identify all team members early on and include every member of the group communications from the outset.
6. Do not be too proud to seek help from outside the project team.
7. Go to extraordinary lengths to encourage team members to take risks.
8. Do not all ways call on management to solve problems!

Two of these categories of knowledge including Quantitative Data and Theoretical Tools are subsumed under the general categories of knowledge. The four categories of knowledge specific engineering are

- Fundamental Design Principles
- Criteria and Specifications
- Practical Constraints
- Design Instrumentalities

The categories of General and Engineering knowledgeare graphically presented in figure 2.

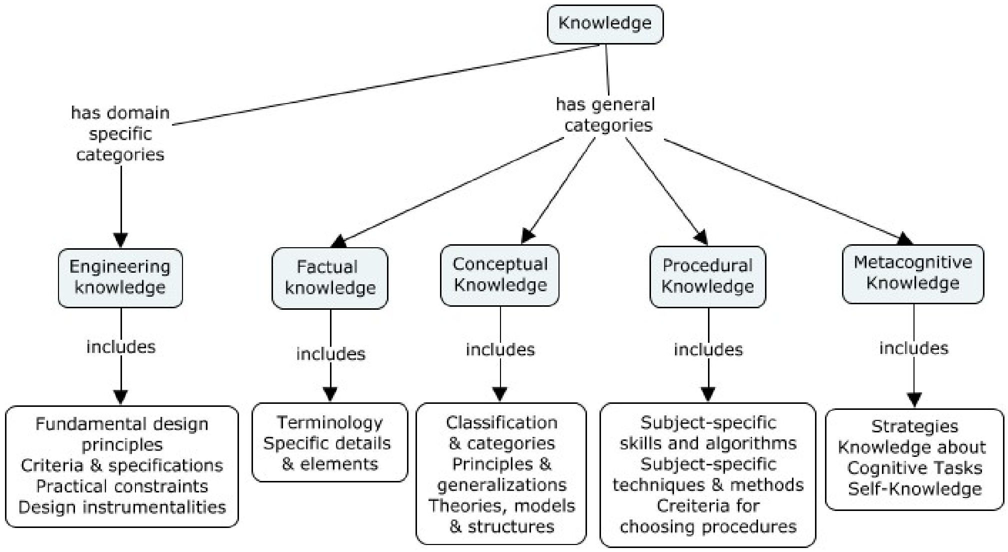

Fig. 2: Categories of General and Engineering Knowledge

4.4 In Summary

Revised Bloom's taxonomy of learning, teaching, and assessment treats the cognitive domain as two-dimensional with six cognitive processes and four categories of knowledge.The six cognitive processes are Remember, Understand, Apply, Analyze, Evaluate, and Create and they are hierarchical in nature. Four general types of knowledge are factual, conceptual, procedural, and metacognitive. Metacognitive knowledge, in simplest terms, is knowledge about cognition. However, To these we add four additional categories of knowledge specific to Engineering proposed by Vincenti. The cognitive domain is represented under Revised Bloom Vincenti (RBV) taxonomy as in figure 3. It is believed that there are also categories of knowledge specific to Social Sciences, Management, and Computing.

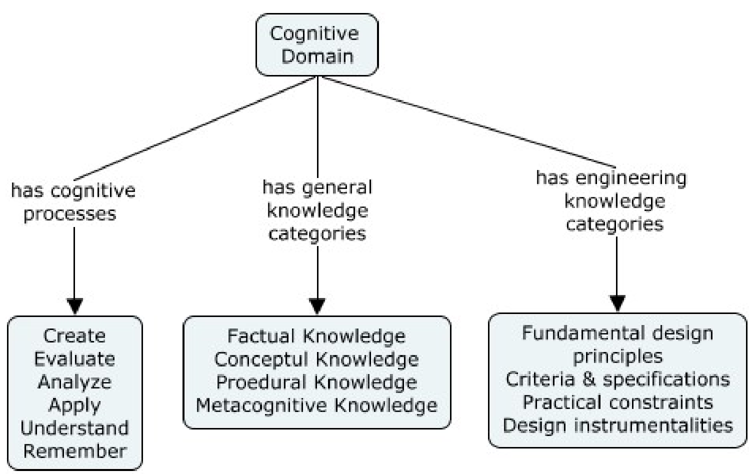

Fig. 3: Cognitive domain as per RBV taxonomy

CHAPTER 5

Affective Domain

Many researchers believe that non-cognitive factors and skills are more important than cognitive aspects in educative processes. Grit, tenacity, curiosity, attitudes, self-concept, self-efficacy, anxiety coping strategies, motivation, perseverance, confidence are among those frequently referred to as non-cognitive factors. Many of these factors fall into the affective domain.

Every one of us develops a unique personality or self-concept in the process of interacting with and growing in the physical and social environment. We reject pain and embrace pleasure. This happens when we become autonomous, make our own decisions and choices in structuring the experiences, we become what we can become, we actualize our possibilities and potentialities, we achieve unity of personality and blend or integrate our experiences into a coherent, unified, and consistent system of feelings, ideas, and attitudes.

An individual growing in a dynamic, pluralistic, urban-industrial society encounters a fast-changing set of circumstances. Young persons are confronted by various experiences that were not part of the pre-adult experience of elders. Adults may become confused as they attempt to reconcile their past inconsistencies and contradictions. Such confusion is easily communicated to the younger generation. Such a climate is not conducive to healthy psychological development. Affective education has a significant role in resolving this problem.

The Affective Domain is most associated with feelings and emotions. It is usually displayed in positive or negative reactions to given events, objects, behaviors, policies, or situations. Affective behaviors are accompanied by varying degrees of feelings and reflect distinct "approach" or "avoidance" predispositions. A person's experience in interacting with the environment shapes the nature and scope of affective responses. (Pierce and Gray, 1981)

An "affect" is any type or degree of positive or negative feeling toward environmental circumstances, expressed through an observable display of emotive, reactive, or evaluative behavior.

Attitudes are unexamined inclinations or dispositions for or against objects, ideas, or actions. They serve as general feeling indicators that usually influence behavior.

Values are tested dispositional insights for or against objects, ideas, or actions. When someone values something, he/she assigns worth to it concerning goals and purposes. Values (enjoying, conserving, respecting, supporting, etc.) serve as specific guides for consistent behavior.

Activities in all three domains involve Sensory Inputs, Mental Processing, and Output. Pierce-Gray taxonomy recognizes this three-step process and classifies the affective domain in terms of increments in cognition.

1. Perceive

- Emotive Imprinting
- Response Setting

Sample Outcome: Listen to others' points of view on ethical issues in genetics and biotechnology.

Action verbs: ask, choose, describe, follow, give, hold, identify, locate, name, point to, select, sit, erect, reply and use

2. React

- Emoting
- Recognizing
- Controlling

Sample Outcomes:

- Discusses the nature of his/her past and present reactions to the ethical issues in genetics and biotechnology
- Discusses with classmates whether he/she should continue to react in the same way to the ethical issues in genetics and biotechnology
- Assists teammates in resolving ethical issues in genetics and biotechnology.

Action Verbs: answer, assist, aid, comply, conform, discuss, greet, help, label, perform, practice, present, read, recite, report, select, tell, and write.

3. Conform

- Artificial Attitude
- Consistent Attitude
- Rationalized Attitude

Sample Outcomes:

- Justify the position he/she has taken regarding the use of genetic experimentation from an ethical point of view.
- Display commitment to using ethical standards when resolving ethical problems in genetics and biotechnology.

Action verbs: Complete, demonstrate, differentiate, explain, follow, form, initiate, invite, join, justify, propose, read, report, select, share, study, and work.

4. Validate

- Examining Values
- Accepting Values

Sample Outcome:

- Write a two-page paper explaining why he/she intends to maintain, revise, or discard his/her present stance on the current genetic experimentation from an ethical point of view.
- Adhere to ethical standards in discussing specified issues in genetics and biotechnology.

Action verbs: Explain, follow, justify, propose, read, report, select, share, study, and work

5. Affective Judge

- Establishing Value Criteria
- Value Judging

Sample Outcome: Given multiple stands taken on ethical issues on genetics and biotechnology by separate groups, develop criteria based on which one can judge the ethical issues.

Action verbs: Adhere, alter, arrange, combine, develop, complete, defend, explain, formulate, generalize, identify, integrate, and modify.

6. Affective Create

- Integrating Values
- Inspirational Insight

Sample Outcome: Prepare a report that attempts to present his/her ethical standard on genetics and biotechnology supported by the assumptions made and data collected.

Action verbs: Act, create, influence, modify, perform, propose, revise, serve, solve, support.

Teachers can set up affective goals to be attained in their courses. These goals can be classified as

- Behavioral Goals are attitudes and values related to the rights, feelings, and property of others, including the fellow students, teachers, and the institution.
- Procedural Goals are attitudes and values concerned with demonstrating respect for critical thinking, objectivity, evidence, and logical analysis.
- Substantive Goals are attitudes and values related to economic, social, political, ethical, and aesthetic questions and importance to a pluralistic society.

In addressing the activities in the affective domain, the teacher must choose a position. Should he/she try to avoid controversy? Try to be the impartial (and neutral) observer? Try to instill acceptable values in students? It is suggested that the teacher is to take the role of “defensible partisanship” in a culturally pluralistic and democratically oriented society. Teacher’s attitudes should be that values are not taught, but they are critically examined.

CHAPTER 6

Psychomotor Domain

Learning in the psychomotor domain involves motor, muscular activities. Psychomotor learning also occurs in combination with cognitive and affective domain learning. It is demonstrated by physical skills that are acquired through practice. The development of these skills requires practice and is measured in terms of speed, precision, distance, procedures, or techniques in execution. Riding a bicycle, driving a car, playing a musical instrument, typing, acting, and running are dominantly psychomotor activities. The psychomotor activities become important and even dominant in courses of programs in Theatre, Music, Painting, Sports, Medicine, Nursing, Dentistry, Emergency Medical Services, etc.

Pierce-Gray taxonomy of psychomotor domain identifies six levels: Psychomotor Perceive, Activate, Execute,Maneuvere, Psychomotor Judge, and Psychomotor Create.

There are several taxonomies of the psychomotor domain due to Ragsdale, Simpson, Kibler, Barker and Miles, Hauenstein, and Harrow.

Activities in all three domains involve Sensory Inputs, Mental Processing, and Output. Pierce-Gray taxonomy recognizes this three-step process and classifies the psychomotor domain in terms of increments in cognition.

1. Psychomotor Perceive

- Sensory Transmission
- Physio Functional Maintenance

The ability to use sensory cues to guide motor activity. There is the readiness to act. It includes mental, physical, and emotional sets. These three sets are dispositions that predetermine a person's response to different situations

Outcome Sample: Estimate where a ball will land after it is thrown and then moving to the correct location to catch the ball.

Action verbs: Choose, describe, detect, differentiate, distinguish, identify, isolate, relate, and select.

2. Activate

- Physical Outputs
- Mimicry
- Deliberate Modelling

Activation is a 3-stage process: Physical Outputs, Mimicry, and Deliberate Modelling. The initial stages in learning a complex skill that includes imitation and trial and error. Adequacy of performance is achieved by practicing.

Outcome Samples:

- Perform proper breathing techniques.
- Reproduce basic stances, including aramandi, sama, muzhumandi, and the related exercises.

Action verbs: Copy, trace, follow, react, reproduce, respond

3. Execute

- Task Execution
- Operational Execution
- Skilled Execution

Execute is also a 3-stage process: Task Execution, Operational Execution, and Skilled Execution. Learned responses have become habitual, and the movements can be performed with some confidence and proficiency

Outcome samples:

- Operate a computer quickly and accurately.
- Perform tha-thai-thamadavus.

Action verbs: Perform skilfully, react fast, reproduce fast, and respond fast

4. Maneuvere

- Inspecting Skills
- Selecting Skills

The maneuvere is a 2-stage process: Inspecting Skills and Selecting Skills. Skills are well developed, and the individual can modify movement patterns to fit unique requirements.

Outcome Samples:

- Perform a task with a machine that it was not originally intended to do.
- Link different movements together.
- Prioritize equipment to carry fewer loads in my backpack.

Action verbs: Adapt, alter, change, rearrange, reorganize, revise, vary, perform, link, and prioritize.

5. Psychomotor Judge

- Establishing Performance Criteria
- Performance Judging

Psychomotor Judge is a 2-stage process: Establishing Performance Criteria and Performance Judging. Skill judging involves more cognitive activity than the lower levels. Actual psychomotor activities even absent for the individual making a judgment.

Outcome Samples:

- Judge the singing performance of participants.
- Judge the quality of a dance performance.

Action verbs: Judge, critique, differentiate, mark, and select

6. Psychomotor Create

- Combining Skills
- Performance Insight

Psychomotor Create is a 2-stage process: Combining Skills and Performance Insight. Skills are combined to create a new whole.

Outcome Samples:

- Develop a new and comprehensive training program.
- Create a new gymnastic routine.
- Perform a Kuchipudi dance for a given Sanskrit poem.
- Sing a given song in a specified Raga.

Action verbs: Create, develop, perform, arrange, build, combine, compose, construct, design, initiate, make, and originate.

Cognitive, affective, and psychomotor activities are not independent of one another. Higher levels of affective and psychomotor activities involve more cognitive activities. Instruction needs to pay attention to these dependencies, especially integrating affective and psychomotor elements into cognitive activities in general courses.

For completion, we can also include Spiritual Domain as the fourth domain. The exploration of that domain is beyond the scope of this note. The four domains and their taxonomies are presented as a concept map in figure 4.

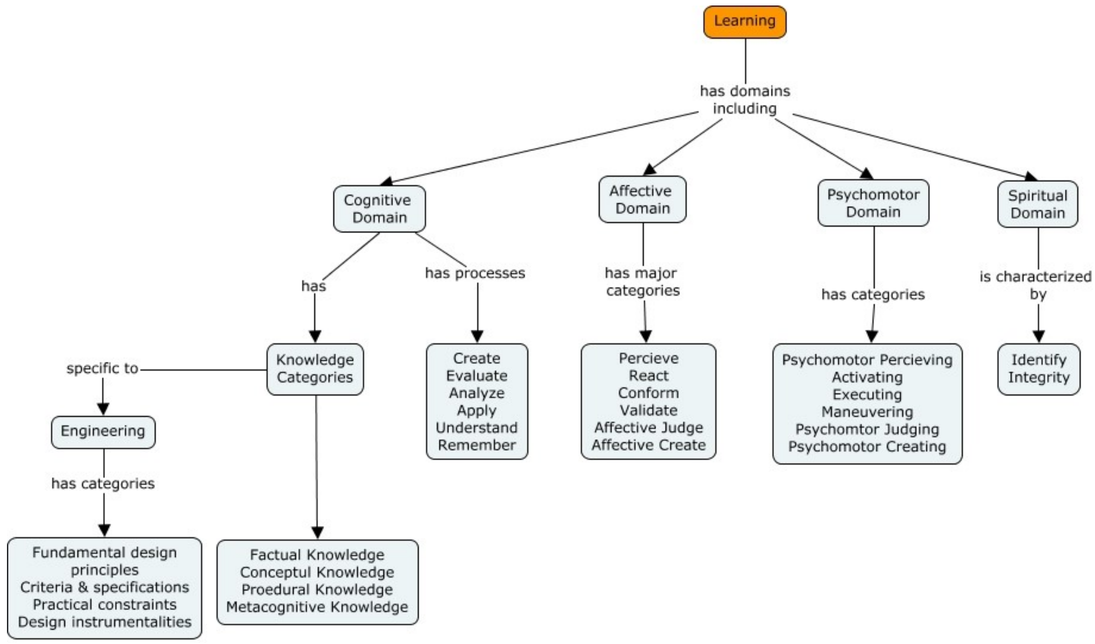

Fig. 4: Taxonomy of the four domains of learning

CHAPTER 7

Taxonomy Table

Cognitive Domain has two dimensions: Cognitive Processes (Levels) and Knowledge Categories. There are six cognitive processes and four general categories of knowledge. A table with the six rows of cognitive processes and four categories of knowledge can serve as an excellent tool to deal with several issues of teaching and learning. Such a table known as the Revised Bloom's taxonomy table is shown in figure 5.

Cognitive Processes	Knowledge Categories			
	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Fig. 5: Revised Bloom's Taxonomy Table of the cognitive domain

A cell of the Taxonomy Table can be numbered by its cognitive process (1 to 6) and its knowledge category (1 to 4). The cell (4, 3) represents Analyse-Procedural outcome, instructional activity, and/or assessment. As there is a hierarchy among cognitive processes, the cell (4, *) represents a more complex (higher level) cognitive activity than the cell (3, *), but not a necessarily more difficult activity. The cell (4, *) implies all activities in (3, *), (2, *) and (1. *) cells.

Majority of the courses in any engineering program belong to Basic Science, Engineering Science, and Humanities, Social Science and Management. Many courses that come under the category of Professional Core also belong to the category of Engineering Science. Engineering courses, small in number, and Engineering Science courses to which the teacher decides to incorporate some engineering will address four additional categories of knowledge of Vincenti. The taxonomy table for such courses, referred to as Revised Bloom Vicenti (RBV) Taxonomy Table, will have six cognitive processes (as rows) and eight knowledge categories (as columns) is shown in figure 6.

Cognitive Processes	Knowledge Categories							
	F	C	P	M	FDP	C & S	PC	DI
Remember								
Understand								
Apply								
Analyze								
Evaluate								
Create								

F: Factual, C: Conceptual, P: Procedural, M: Metacognitive, FDP: Fundamental Design Principle, C&S: Criteria and Specifications, PC: Practical Constraints, DI: Design Instrumentalities

Fig. 6: RBV taxonomy table

The three elements of a Course are

- Course Outcomes (CO) representing what the students should be able to do at the end of the course
- Assessment Items (AI) of the course include assignments, tests, presentations, reports, examinations, etc.
- Instructional Activities (IA) to facilitate the learners attaining the course outcomes

Good learning can take place when there is alignment between the three elements of a course. This would mean

- Assessment should be in alignment with the course outcomes.
- Instruction should be in alignment with the assessment and course outcomes.

An element of a course can be tagged by its cognitive level (action verb) and knowledge categories (can be more than one). An element can be in one or more cells of the taxonomy table based on tagging. Alignment among the elements of a course means all the aligned elements being in the same cell of the RB taxonomy table, as shown in figure 7.

Cognitive Processes	Knowledge Categories			
	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply			CO3, IA3, AI3	
Analyze				
Evaluate				
Create				

Fig. 7: Alignment of the three elements in the RB taxonomy table

The taxonomy table can also be used to check for alignment among the three elements of a course. Consider the taxonomy table shown in figure 8. In the table

Cognitive Processes	Knowledge Categories			
	Factual	Conceptual	Procedural	Metacognitive
Remember	AI5	IA5, AI5	IA4	
Understand		IA5, AI5	IA4	
Apply		IA5, AI5	CO4, AI4	
Analyze		CO5		
Evaluate				
Create				

Fig. 8: Partial or no alignmentin RB taxonomy table

- CO4 is in Apply-Procedure Cell, Instructional Activity is also in the cell (3, 3), but AI4 items are either in the cell (3, 1) or (3, 2).
- The absence of Assessment Items in the cell (3, 3) is unacceptable.
- CO5 is in the Analyze-Conceptual cell, but AI5 and IA5 are not in the cell (4, 2). This is unacceptable.
- AI5 is also in the cell (1, 1) is not related to the "Analyze" cognitive process nor to the "Conceptual" category of knowledge. It is also not acceptable.

Proper alignment requires

- Course Outcome and its related Instructional Activities should be in complete alignment (locatable in the same cells)
- While some (small percentage) assessment items can be in cells representing cognitive levels lower than that of CO, a significant percentage of Assessment Items should be in the same cell as that of CO.

Taxonomy table can facilitate achieving a specified alignment among the three elements of a course and eliminate chance occurrences, can help in designing of well-structured Test Item

Banks, and consequently, validity and reliability, two important properties of assessment can be achieved and can serve as a useful tool for organizing tutoring.

APierce-Gray TaxonomyTablefor affectivedomain can be drawn as shown in figure 9. There is a hierarchy in affective levels as well as affective goals. Procedural affective goals are at a higher level than those of behavioral affective goals, and substantive affective goals are at a higher level than those of procedural affective goals.

Affective Level	Behavioral Goal	Procedural Goal	Substantial Goal
Perceive			
React			
Conform			
Validate			
Affective Judge			
Affective Create			

Fig. 9: Pierce-Gray Taxonomy Table of the affective domain

CHAPTER 8

Program Educational Objectives

PEOs are what the graduates of the program are expected to achieve within 3 to 4 years of completing the program. They can be abstract to some extent but must be smaller in number and must be achievable and follow from Vision and Mission. They should be identified following an established process. The process should be similar to the one followed for Vision and Mission. The process should be documented, and records of process implementation should be maintained. PEOs must be shared with all stakeholders!

The key elements of PEO statements include:

- Professional success
- Life-long learning, Higher Education, Research
- Ethical professional practice
- Communication skills
- Team player, etc.

The relationship of PEOs to the Mission of the Department is shown in figure 10.

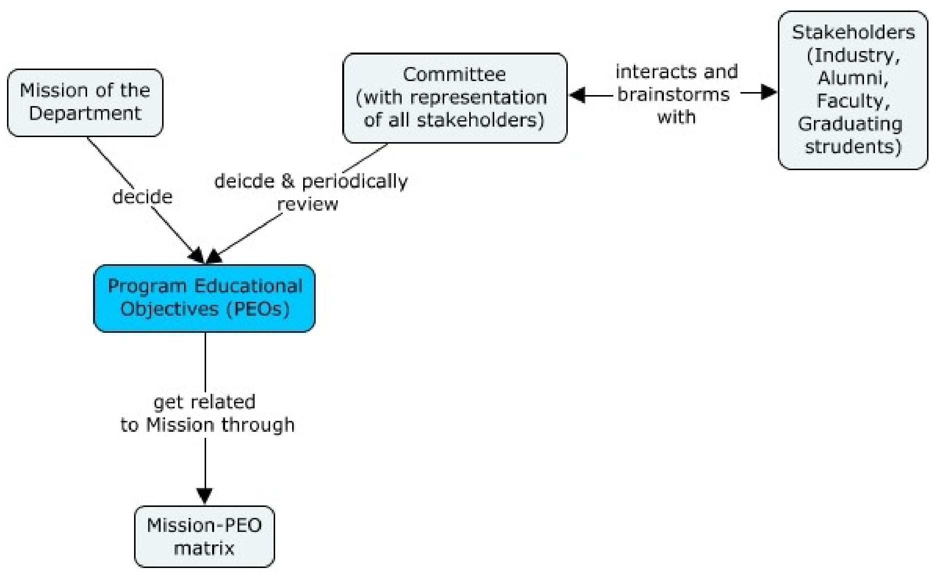

Fig. 10: Relationship of PEO to Mission of the Department

Sample PEOs

Graduates of BE program in Electrical and Electronics Engineering will

PEO1. Engage in the design of systems, tools, and applications in the field of electrical and electronics engineering and allied engineering industries

PEO2. Apply the knowledge of electrical and electronics engineering to solve problems of social relevance and/or pursue higher education and research

PEO3. Work effectively as individuals and as team members in multidisciplinary projects

PEO4. Engage in lifelong learning, career enhancement and adapt to changing professional and societal needs

Graduates of BE program in Information Technology will

PEO1. Manage the information technology resources of an individual or organization.

PEO2. Anticipate the changing direction of information technology and evaluate and communicate the likely utility of new technologies to an individual or organization.

PEO3. Contribute to the scientific, mathematical, and theoretical foundations on which information technologies are built.

PEO4. Live and work as a contributing, well-rounded member of society.

Graduates of BE program in Civil Engineering will

PEO1. Survey, map, and plan layouts for buildings, structures, and alignments for canals and roads

PEO2. Specify, design, supervise, test, and evaluate foundations and superstructures for residences, public buildings, industries, irrigation structures, powerhouses, highways, railways, airways, docks, and harbours.

PEO3. Specify, design, supervise, and evaluate water conveying systems and environmental engineering systems.

PEO4. Work with water resources hydrological systems to estimate safe and assured withdrawals.

PEO5. Work in a team using standard tools and environments to achieve project objectives.

Graduates of BE program in Computer Science and Engineering will

PEO1. Specify, design, develop, test, and maintain usable software systems that behave reliably and efficiently and satisfy all the requirements that customers have defined for them.

PEO2. Develop software systems that would perform tasks related to Research, Education and Training, and E-governance.

PEO3. Work in a team using standard tools and environments to achieve project objectives.

Graduates of BE program in Electronics and Communication Engineering will

PEO1. Specify, design, prototype, and test modern electronic systems that perform analog and digital processing functions.

PEO2. Architect, partition, and select appropriate technologies for the implementation of a specified communication system.

PEO3. Design essential elements (circuits and antennas) of modern RF/Wireless communication systems.

PEO4. Work in a team using common tools and environments to achieve project objectives.

CHAPTER 9

Program Outcomes

Program Outcomes (POs) are what graduates of any engineering program should attain at the time of graduation. Program Outcomes (POs) are outcomes that are non-specific to a program. National Board of Accreditation identified the POs. They are like and in alignment with the Graduate Attributes of the Washington Accord. They are twelve in number. All the 12 Program Outcomes must be attained, not necessarily to the same level, by all engineering students at the time of graduation. Only five of twelve POs are dominantly technical and disciplinary outcomes, and the remaining are professional outcomes, also known as generic or transferable (skills) outcomes. Three POs mention complex engineering problems. Two POs mention complex engineering activities. Two POs mention contextual knowledge.

Designing and conducting undergraduate programs in Engineering to attain a set of POs is a new experience to Indian Universities and Engineering Colleges. These POs cannot always be addressed through courses specifically designed for a PO or a set of POs. These POs need to be addressed through the core courses of the program under consideration. We need to understand the nature of elements of the POs selected and identify activities that address these elements. The activities planned to address POs should be amenable to the measurement of their attainment by students.

Complex Engineering Problems involve wide-ranging or conflicting technical, engineering, and other issues and have no apparent solutions. They involve diverse groups of stakeholders with widely varying needs and can have significant consequences in a range of contexts. Complexity is characterized by many variables, phenomena with widely different time constants, presence of noise, independent multiple decision making, and systems with many negative and positive feedback loops. They have possibly many parts or sub-problems.

Some examples of **Complex Engineering Problems** are:

- Plan for supplying water for irrigation and drinking to a group of villages in an arid zone
- Design an instrumentation system for managing available water and its utilization in a river basin.
- Design a system to construct large-scale poor and middle-class housing in towns with populations less than two lakhs.
- Improve the quality of power supply to a city or a district.
- Design a system for managing an elephant corridor without conflict between humans and elephants.

Complex Engineering Activities involve using diverse resources (people, money, equipment, materials, information, and technologies). They require the resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering, or other issues and involve creative use of knowledge of engineering principles. They can extend beyond previous experiences.

The Program Outcomes, as given by the NBA, are:

PO1. **Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. **Problem Analysis:** Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using the first principles of mathematics, natural sciences, and engineering sciences.

PO3. **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.

PO4. **Conduct Investigations of Complex problems:** Use research-based knowledge and research methods, including the design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. **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.

PO6. **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.

PO7. **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, demonstrate the knowledge of, and need for sustainable development.

PO8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities, and norms of the engineering practice

PO9. **Individual and Teamwork:** Function effectively as an individual and as a member or leader in diverse teams and in multidisciplinary settings.

PO10. **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.

PO11. **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.

PO12. **Life-Long Learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning (LLL) in the broadest context of technological change.

The PO statements are complex, and each PO has several keywords. All the concerned persons, including administrators, Members of Boards of Studies, Principals, and teachers, need to understand the features of PO statements and identify activities that can facilitate the attainment of these POs. Some of these aspects of POs are presented in the following:

PO1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

- The majority of engineering courses mainly address this outcome.
- Assessment in many institutions falls far short of solving engineering problems, leave alone complex engineering problems.
- The end of the chapter problems will at least moderately address this PO.
- The majority of courses belong to either Basic Sciences or Engineering Sciences, which do not address engineering problems directly.

Some activities that can address **PO1** are:

- Solve the end of the chapter problems.
- Understand the context in which a given engineering problem was formulated.
- Understand the nature of complex engineering problems.
- Give examples of complex engineering problems.
- Give multiple solutions to given complex engineering problems.

PO2.Problem Analysis: Identify, formulate, research literature, and complex engineering problems reaching substantiated conclusions using the first principles of mathematics, natural sciences, and engineering sciences.

PO2 involves:

- Problem identification
- Formulation
- Researching literature
- Analyzing and
- Reaching substantiated conclusions

It involves problem statement construction, problem formulation and abstraction, information and data collection, model translation, validation, experimental design, experimentation, interpretation of results, implementation, documentation, feedback, and improvement.

The "substantiated conclusions" should be arrived at using the first principles of mathematics, natural sciences, and engineering sciences and not based on opinion or intuition.

The majority of the programs do not have courses that address even a small subset of these activities.

Mini and major projects can only include these activities, provided they are properly orchestrated.

This PO can also be addressed through group assignments in some courses. These require considerable planning on behalf of the instructor and developing appropriate rubrics for evaluation of the performance of each member of the group

Some activities that can address **PO2** are:

- Identify complex problems that dominantly belong to the engineering branch of concern.
- Make appropriate assumptions, especially about the context in which the solutions are being sought, that help formulate an identified complex engineering problem.
- Justify the assumptions made in formulating a complex engineering problem based on a survey of the related literature.
- Understand the requirements of end-users of solutions to the problems.
- Explore and select a method of solving the formulated problem.
- Specify the (hardware/software) products and processes that can solve the formulated engineering problem.

PO3: 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.

PO3 involves

- Designing solutions for engineering problems can only be experienced through projects and assignments, and these are time-consuming activities and hence cannot be included in limited time written examinations.
- Components of systems can be designed through smaller assignments in some identified courses.
- The design criteria and specifications of components and processes need to be evolved from the solutions to a given problem.
- These criteria and specifications should be developed, taking public health and safety issues and the cultural, societal, and environmental considerations.
- Issues related to public health, safety, and environmental consideration can be addressed through design using relevant **standards.**
- Cultural and societal considerations will require inputs from non-engineering fields and get incorporated into non-functional specifications.

Some activities that can address **PO3** are:

- Understand the role of public health and safety and the cultural, societal, and environmental considerations in determining the non-functional requirements of products and processes.
- Identify the standards that apply to the product or process that needs to be designed and developed.
- Design components and sub-systems as per specifications.
- Specify the testing process to check the performance of the designed product or process.
- Document the design of products, components, and processes.

PO4. Conduct Investigations of Complex Problems: Use research-based knowledge and research methods, including the design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO4 involves

- Use research-based knowledge to provide valid conclusions. Most of the core courses do not generally offer such learning experiences. It requires collecting a set of research papers that can be understood by the UG students and posing a set of questions.
- Understand the research methods relevant to the discipline of concern.
- It will become challenging to design and implement such exercises, particularly at the undergraduate level in most institutions.
- The research method of "design of experiments" can be experienced through open-ended experiments in some laboratories
- The research method of "analysis and interpretation of data, and synthesis of the information" requires a collection of significant amounts of data related to a context and posing questions that can lead to the synthesis of information. Such contexts are more readily identified in subjects like Data Bases, Material Science related subjects, Chemical Process Optimization, Nano Technology, and Device and Sensor Design

Some activities that can address **PO4** are:

- Plan and perform experiments/surveys and collect the data as per the applicable standards.
- Perform the necessary calculations and data reduction to draw valid conclusions.
- Present the results in a standard format.

PO5. 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

PO5 involves

- Creating, selecting, and/or applying modern engineering and IT tools

- Creating tools that can only be attempted through projects, preferably by multidisciplinary teams
- Selecting that can only be a paper-level exercise comparing different tools for a specified application.
- Incorporating IT tools into the laboratories. (Modern measurement and testing tools are costly, and very few institutions can afford them at the undergraduate level, but virtual laboratories can provide an avenue.)
- Modeling methods and simulation for predicting the behavior of complex engineering systems (While modeling is part of several engineering courses, simulation can be extensively used at the classroom level and in laboratories.)

Some activities that address **PO5** are

- Determine the requirements of a simulation tool for a class of engineering problems.
- Create tools for simulation and solving a class of engineering problems
- Select the most cost-effective tool from the commercially available engineering and IT tools for addressing a class of engineering problems.
- Understand the limitations of given engineering or IT tools.
- Use the engineering and IT tools made available by the Department.

PO6. 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

PO6 is important because

- Technology is both the cause and effect of societal changes. Engineers produce products and services apparently for the benefit of the society
- There are societal, health, safety, legal, and cultural issues for all products and services, which are context-dependent.
- Students should experience/understand the relationship between products and services to people/society in various contexts.

Activities that can address **PO6** are:

- Understand the goals and working of relevant professional society.
- Identify when and where engineers interact with society through their professional activities.
- Understand the responsibilities implied in one’s professional practice.
- Case studies in some courses will bring the students' attention to product/service-people relationships in several contexts. The assessment could be in terms of the student’s perception of his responsibilities.
- The evaluation rubrics for projects can incorporate elements of engineer-society interaction.

- There can be courses on Technology-Society interaction like Energy and Society, Water and Society, Complexity, Housing, and Sustainability to address this PO.

PO7.Environment and Sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, demonstrate the knowledge of, and need sustainable development.

Attainment of PO7 requires Students to understand the need for sustainable development, the impact of engineering solutions on people and the environment, and to demonstrate the knowledge of what can lead to sustainable development.

PO7 may be addressed through:

- Courses on technology and society and sustainability
- Case studies in some courses will bring the attention of the students to sustainability issues. The assessment could be in terms of the student's perception of the impact of engineering solutions on sustainability.
- Understanding what sustainable growth is
- Understanding the impact of a given technology on the environment and sustainability
- Analyzing the impact of a given engineering solution on the environment and sustainability

PO8.Ethics: Apply ethical principles and commit to professional ethics and responsibilities, and norms of the engineering practice

The application of ethical principles requires moral autonomy. Moral autonomy means conduct and principles of action are owned, decisions and actions are based on critical reflection and not a passive adoption of some "code," and moral beliefs and attitudes are integrated into the core of one's personality and lead to committed action. Professional engineering ethics are rules and standards governing the conduct of engineers in their roles as professionals. Every professional engineering society will define a code of ethics for its practitioners. Students should understand the nature of ethical problems they face in engineering practices and the ethical norms of engineering practice and their implications on professional decision-making.

PO8 can be addressed through:

- A dedicated course on professional ethics and case studies with a focus on ethical issues and their resolutions
- Identifying the deviations of an engineering solution from the accepted professional practices
- Identify the impact of an engineering solution on different groups of persons.
- Recognizing the ethical dilemma in the case study presented.
- Proposing actions that minimize damage and synthesizing solutions rather than judge the players in ethically complex situations presented as case studies

PO9. Individual and teamwork: Function effectively as an individual and as a member or leader in diverse teams and in multidisciplinary settings.

All engineering activities in an organization are group activities. The group needs to work as an effective team to meet the goals of a project. The industry considers the ability to work in a team as an essential characteristic of all engineers. After becoming a team member and identifying his/her role, an individual should work effectively to achieve the team's objectives despite personal differences from other team members. It is necessary to develop rubrics to measure how good a team member is and make the evaluation count. The students should be provided with experiences as members or leaders in technical, semi-technical, and non-technical teams. It is worthwhile to arrange for coaching to students on becoming members of teams.

Some activities that facilitate the attainment of **PO9** are:

- Group assignments that involve group decision making, division of work through negotiation
- Group projects
- Co-curricular activities that will require a group
- Activities through e-groups

PO10.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.

An engineer needs to communicate effectively with his own community and is also required to communicate with lay-educated persons, including customers of one's own organization and society at large. All engineers work in groups. This requires all members to document and present their day-to-day work in commonly agreed formats. As all formal professional engineering activities are conducted in English, many colleges have one course in English and Professional Communication. Several writing exercises should be embedded in some courses with evaluation rubrics having elements related to correctness and writing skills. Technical writing should be given adequate weightage in evaluating project reports.

Some activities that promote attainment of **PO10** are:

- Write technical documents (reports) that get evaluated as per declared rubrics.
- Make short presentations to peers and laypersons that get evaluated as per declared rubrics.
- Give feedback on a presented activity.
- Document the feedback given on a presented activity
- Encourage and support group members in meeting the goals.

PO11. 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

Most of the engineering activities are conducted in project mode. A project can be multidisciplinary. Projects have limited financial sources and specified timelines.

Attainment of **PO11** can be facilitated through:

- A course on Engineering Management and/or Project Management
- Well-orchestrated mini and main projects
- The rubrics of evaluation should reflect the student's understanding of project management and estimation of cost.
- Determining the time and financial resources required to implement a project
- Analyzing the performance of an organization from its balance sheet

PO12. Life-Long Learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning (LLL) in the broadest context of technological change.

LLL is a concept of learning that enables us to deal with continuous change in an engineer's life and practice. Lifelong learning skill is the ability to "continue one's self-education beyond the end of formal schooling." The technological changes in the last hundred years should convince us to recognize that learning is a continuous and life-long pursuit. It is impossible to progress in one's career only with the knowledge and skillset acquired at graduation. If students are to be motivated and equipped to continue teaching themselves, their formal education must go beyond the presentation of predetermined content. Projects of all kinds generally promote self-learning, but appropriate rubrics are necessary for measurement. LLL can be promoted by helping students to understand their learning processes, requiring students to take responsibility for their learning, creating an atmosphere that fosters confidence in students' ability to succeed, and helping students see schooling and education as personally relevant to their interests and goals.

Activities that promote **PO12** are:

- Determine the knowledge, skills, and attitudes needed at the beginning of a project (writing a report and/or developing a product/process)
- Develop strategies to acquire the required knowledge and skills.
- Acquire the required knowledge and skills outside the classroom.
- Participate in professional development, professional society activities, and co-curricular and extracurricular activities

Chapter10

Program Specific Outcomes

Program Specific Outcomes (PSOs) are outcomes that are specific to a program. PSOs characterize the specificity of the core (core courses) of a program. PSOs of an engineering program can only be two to four in number. All programs should be designed and conducted to attain the POs identified by the NBA and PSOs identified by the concerned Boards of Studies. The PSO statement should start with one or more action verbs. The action verbs should be followed by clearly identified technical objects, and if required, by the conditions under which the actions are to be performed.

Some action verbs for writing PSOs

- Formulate, specify, conceive, design, plan, architect, build, implement, test, operate
- Select
- Analyze, determine, estimate, calculate

The Boards of Studies need to rewrite the PSOs whenever the curriculum is reviewed and changed. The PSOs are reviewed once in four to five years, generally when the program's curriculum is changed, following a well-documented process. The relationship of PEOs to POs/PSOs is shown in figure 11.

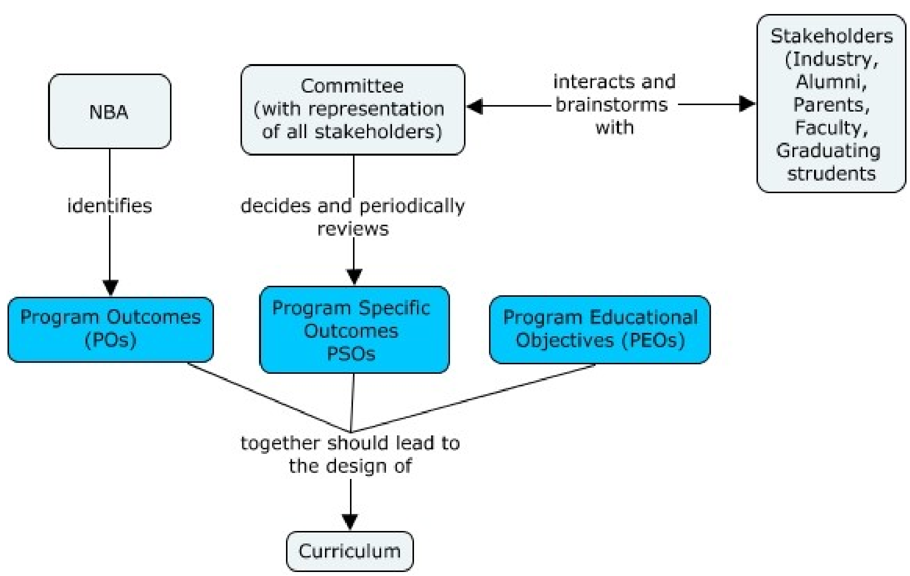

Fig. 11: Relationship between POs/PSOs and curriculum

Some sample PSOs prepared by groups of faculty members from different branches are given below. It is not necessary to take them as references.

Mechanical Engineering

Sample 1

PSO1. Design and evaluate mechanical components and systems using state-of-the-art IT tools.

PSO2. Plan the manufacturing of given mechanical components and systems (methods design, process plan, process automation, and manufacturing methods).

PSO3. Apply modern management methods to manufacturing of components and systems. and design quality assurance systems.

Sample 2

PSO1. Design and evaluate mechanical components and systems using state-of-the-art IT tools.

PSO2. Design and evaluate thermal systems, including IC engines, refrigerating, air-conditioning, and power generating systems.

PSO3. Plan, including methods design, process plan, process automation, and quality assurance systems to manufacture given mechanical components and systems.

PSO4. Apply modern management methods to the manufacture of components and systems.

Sample 3

PSO1. Specify and design machine elements using Solid Edge / CATIA and Ansys.

PSO2. Specify and design heating, ventilation & air-conditioning systems, electronic systems, solar rooftop water heating systems using an experimental approach or /and CFD tools and determine their thermal performance.

PSO3. Understand the properties of composite materials and their manufacturing.

PSO4. Plan efficient, safe, and cost-effective manufacturing of mechanical components and products

Sample 4

PSO1. Specify and design machine elements using ProE and Ansys.

PSO2. Plan the manufacture of given mechanical elements and estimate the cost of their manufacturing.

PSO3. Determine the performance of thermal systems, including IC engines, refrigeration, and air-conditioning systems, and design refrigeration and air-conditioning systems as per the requirement specifications.

PSO4. Determine the performance of turbomachines (air compressors, turbines, and pumps) and design critical parts of turbomachines.

Civil Engineering

Sample 1

PSO1. Survey, map, and plan layouts for buildings, structures, and alignments for canals and roads.

PSO2. Specify, design, supervise, test, and evaluate foundations and superstructures for residences, public buildings, industries, irrigation structures, powerhouses, highways, railways, airways, docks, and harbors.

PSO3. Estimate safe and assured withdrawals and specify, design, and evaluate water conveying systems, hydraulic machines, and surge systems.

PSO4. Formulate, specify, and select environmental engineering systems.

Sample 2

PSO1. Survey, conduct geotechnical investigations, collect data, make feasibility studies, and design as per codal provisions residences, public buildings, industries, irrigation structures, powerhouses, highways, dams, aligning a road or waterway, and creating a township in a region.

PSO2. Understand the impact of water, air, and noise pollution, waste containment methods, and specify design and water, sewerage, and industrial effluent conveying and treatment systems.

PSO3. water resources and hydrological systems to estimate safe, flood discharges and assured withdrawals, and specify and design/select hydraulic machines/systems and surge systems.

PSO4. Understand modern management and construction techniques to complete the projects within the stipulated period and funds.

Electrical and Electronics Engineering

Sample 1

PSO1. Specify, architect, design, and systems that efficiently generate, transmit, distribute and utilize electrical power.

PSO2. Specify, design, prototype, and test modern electronic systems that perform analog and digital processing functions.

Sample 2

PSO1. Specify, architect, and power systems that efficiently generate, transmit and distribute electrical power in the context of present ICT

PSO2. Specify and design modern electrical drive systems and modern lighting systems.

PSO3. Understand the principles and construction of electrical machines and determine their performance through testing.

PSO4. Specify, design, implement and test analog and embedded signal processing electronic systems using the state of the art components and software tools.

Computer Science and Engineering

Sample 1

PSO1. Specify, design, develop, test, and maintain usable software systems that behave reliably and efficiently and satisfy all the requirements that customers have defined for them.

PSO2. Develop software systems that would perform tasks related to Research, Education, and Training, and/or E-governance .

Sample 2

PSO1. Specify, design, and develop system software (Language Translators, Languages, Operating Systems, and User Interface) to allow convenient use of a computer.

PSO2. Determine and optimize the performance of a given algorithm on a given platform.

PSO3. Specify, design, and develop software for intelligent systems.

PSO4. Specify, design, and develop concurrent and parallel programs.

Sample 3

PSO1. Specify, design, develop, test, and manage reliable and efficient application software systems as per user requirements.

PSO2. Specify, design, and develop system software to allow convenient use of computing systems.

PSO3. Specify, design, develop, and test application software systems for the worldwide network of computers.

PSO4. Develop application software that would perform tasks related to Information Management and Mobiles.

Information Technology

Sample 1

PSO1. Explain and apply appropriate information technologies and employ appropriate methodologies to help an individual or organization achieve its goals and objectives.

PSO2. Manage the information technology resources of an individual or organization.

PSO3. Anticipate the changing direction of information technology and evaluate and communicate the likely utility of new technologies to an individual or organization.

PSO4. Develop IT systems that would perform tasks related to E-governance and/or Health Care Management.

Sample 2

PSO1. Explain and plan appropriate information technology to help an individual or organization achieve his/its goals and objectives.

PSO2. Provide IT service to help an individual or organization achieve his/its goals and objectives.

PSO3. Manage the information technology resources of an individual or organization.

PSO4. Anticipate the changing direction of information technology and evaluate and communicate the likely utility of new technologies to an individual or organization.

Electronics and Communication Engineering

Sample 1

PSO1. Specify, design, prototype, and test modern electronic systems that perform analog and digital processing functions.

PSO2. Architect, partition, and select appropriate technologies for the implementation of a specified communication system.

PSO3. Design essential elements (circuits and antennas) of modern RF/Wireless communication systems.

Sample 2

PSO1. Specify, design, prototype, and test electronic systems that perform analog and digital signal processing functions as per user requirements using currently available electronic components.

PSO2. Specify, design, and test power supplies for electronic systems, including battery management and power amplifiers using currently available electronic components.

PSO3. Architect, partition, and select appropriate technologies to implement a specified wired and wireless communication system.

Metallurgy

PSO1. Determine the performance of given metallurgical operations using the core concepts of Thermodynamics and Heat and Mass Transfer.

PSO2. Select processes of extraction of ferrous and non-ferrous metals and alloys from their ores using mineral dressing and extractive metallurgy.

PSO3. Specify the processes to produce products as per specifications using powder technology, metal forming, and foundry technology.

PSO4. Specify the heat treatment processes to modify the properties of metals and alloys for use in specified engineering applications.

PSO5. Specify the processes for metal joining, protecting engineering materials from degradation using the knowledge of principles of wear, electrometallurgy, and corrosion.

Instrumentation and Control

PSO1. Develop the mathematical model of the industrial process and laboratory systems

PSO2. Specify design, implement and test electronic analog and digital signal processing systems

PSO3. Specify, design, build and test process and laboratory instrumentation systems

PSO4. Develop hardware and software tools used in industrial automation systems

Chapter11

Course Outcomes

Graduates of all UG and PG General Programs in India are required to attain the Program Outcomes (POs) identified by the University/College and Program Specific Outcomes (PSOs) identified by the University or the Department offering the Program. POs and PSOs are to be attained through courses, projects, and co-curricular and extra-curricular activities in which the performance of the students is evaluated.

Courses are broadly classified into core courses, electives, ability enhancement courses, and skill enhancement courses. POs and PSOs are to be attained through core courses, ability enhancement courses, and activities in which all students participate. Courses constitute the dominant part of any program. Under the present CBCS (Choice Based Credit System), the courses can be of 3:0:0, 3:0:1, 3:1:0. 4:0:0, 4:0:2, 5:1:0, 0:0:2, 0:0:1, 1:0:2 or1:0:1credits. It should be remembered that One Credit is defined as

> *Program Outcomes (POs) and Program Specific Outcomes (PSOs) are to be attained through core courses, projects, and co-curricular and extra-curricular activities in which the performance of the students is evaluated.*

- One hour of classroom interaction per week over a semester
- One hour of tutorial per week over a semester
- Two hours of laboratory/fieldwork per week over a semester

The course content will have to be realistically adjusted to the number of credits allotted to the course.

Course Outcomes (COs) are what the student should be able to do at the end of a course. It is an effective ability, including attributes, skills, and knowledge, to conduct some activity that is identified successfully. The most important aspect of a CO is that it should be measurable.

Learning Outcomes (Instructional Objectives) as per R.E. Mager (1962), should include three elements

- **Performance**: An outcome statement should always say what the learner should be able to do.
- **Condition**: The outcomes always describe the important conditions, if any, under which the performance is to occur.
- **Criterion**: Whenever possible, an outcome describes the criterion of acceptable performance by describing how well the learner must perform to be considered acceptable.

Learning Outcomes (Instructional Objectives), as per Revised Bloom (2001), will have a common stem: **"Student should be able to."**

- The stem will be followed by a verb phrase and an object of the phrase.
- The verb phrase states the mental process belonging to any of the cognitive levels: Remember, Understand, Apply, Analyse, Evaluate, and Create.
- The object of the phrase states the type of knowledge.

We combine the elements proposed by Mager with the Phrase and Object of Revised Bloom. "Performance" of Mager will now consist of a Phrase and occasionally two Phrases and one or more Objects. We retain the optionality of "Condition" and "Criterion." The proposed structure of the Course Outcome statement in cognitive, affective, and psychomotor domains, in addition to the common stem, consists of "Action," "Knowledge," "Condition," and "Criterion."

The structure of CO statement now, in addition to the common stem, is

- **Action**: Represents a cognitive/ affective/ psychomotor activity the learner should perform. An action is indicated by an action verb, occasionally two, representing the concerned cognitive process (s).
- **Knowledge**: Represents the specific knowledge from any one or more of the four knowledge categories.
- **Condition**: Represents the process the learner is expected to follow or the condition under which to act (This is an optional element of CO).
- **Criterion**: Represents the parameters that characterize the acceptability levels of acting (This is an optional element of CO).

Sometimes it becomes equally important for a student to perform two cognitive processes on given knowledge elements. Only in such cases, two action verbs are used in a CO statement. It is not an artifact to combine two COs into one. Consider the example of a CO

Draw Bode plots for the given dynamic system and determine the gain and phase margins

Drawing and determining are equally important and both processes are related to the same knowledge elements of Bode plots.

Some examples of CO statements are

Sample 1: Calculate major and minor losses associated with fluid flow in piping networks

Action: Calculate (Apply)

Knowledge: major and minor losses associated with fluid flow in piping networks (Conceptual and Procedural)

Condition: None

Criteria: None

Sample 2: Model a spring-mass system as a differential equation

Action: Model (Understand)

Knowledge: spring-mass system (Conceptual)

Condition: as a differential equation

Criteria: None

Sample 3: Determine the dynamic unbalanced conditions of a given mechanical system of rigid objects subjected to force and acceleration

Action: Determine (Apply)

Knowledge: Dynamic unbalanced conditions (Conceptual and Procedural)

Condition: given mechanical system of rigid objects subjected to force and acceleration

Criterion: None

Sample 4: Process data in Hadoop cluster using Hive and Pig scripts

Action: Process (Apply)

Knowledge: data in Hadoop cluster (Conceptual and Procedural)

Condition: using Hive and Pig scripts

Criterion: None

Sample 5: Understand the effect of all the parameters in voltage controlled oscillators through simulation using TINATI.

Action: Understand

Knowledge: effect of all the parameters in voltage controlled oscillators (Conceptual)

Condition: using simulation using TINATI

Criterion: None

Writing COs to represent what the instructor wants his/her students to learn is the first and most important step in designing and conducting a course. The instruction and assessment need to be in alignment with the CO. There are several errors that are likely to be committed inadvertently while writing COs. These are best avoided using a simple checklist for writing Course Outcomes.

The CO

1. Does the CO begin with an action verb (e.g., state, define, explain, calculate, determine, identify, select, design)?
2. Is the CO stated in terms of student performance (rather than teacher performance or subject matter to be covered)?
3. Is the CO stated as a learning product (rather than in terms of the learning process)?
4. Is the CO stated at the proper level of generality and independent of other COs (i.e., is it clear, concise, and readily definable)?

5. Is the CO attainable (do they consider students' background, prerequisite competences, facilities, time available, and so on)?

How many COs should we write for a course? Too small a number does not capture the course adequately and may not serve instruction design that very well. Too many COs make all the processes related to assessment design and computation of the attainment of COs messy and demanding. A 3:0:0, 3:1:0, and 3:0:1 course should have about seven course outcomes. The number of COs of courses carrying a different number of credits can be suitably adjusted.

Attainment of course outcomes is measured using summative assessment instruments. It should be possible to determine the attainment of a CO through the typically followed assessment mechanisms without needing additional instruments.

It is the practice of many Universities to present the syllabus, of course, as a set of Units to facilitate equal attention to all sections of the syllabus. There need not be one to one correspondence between Units of a course and the COs. A Unit can be addressed by more than one CO. A CO, if necessary, can address topics from more than one Unit. The unitization of the syllabus (list of topics) was brought in as an administrative convenience, and not recommended from Outcome Based Education. OBE demands that COs are written first, and the list of topics is identified next. Even if the scope of all COs is not the same, a simple method can resolve the issues of computation of CO attainment.

CO statements need to be tagged with several parameters to plan for proper instruction, assessment, and to compute the attainment of COs, POs, and PSOs. As stated earlier, a CO statement starts with an action verb from one of the cognitive levels, and occasionally by two action verbs from two cognitive levels. The action verb enables us to tag a CO with the Cognitive Level. One can use the acronyms R-Remember, U-Understand, Ap- Apply, An-Analyse, E-Evaluate, and C-Create. As there are no sharp demarcation lines between some cognitive levels, there is a possibility of one Action Verb representing two different cognitive levels. Use judgment in such cases. As mentioned earlier, a CO statement will include one or more categories of knowledge. The CO statement itself may not explicitly indicate all the concerned knowledge categories. Some knowledge categories may be implicitly addressed. The instructor needs to decide these categories based on the proposed design of instruction and assessment.

Each CO is also tagged with the number of classroom sessions likely to be taken to address that CO and the number of laboratory/field trip allocated hours.

If the PSOs are written well, there should not be any ambiguity regarding the PSO addressed by the course under consideration. All the COs of a course are likely to address the same PSO(s).

Many the courses as they are offered at present, particularly in non-autonomous institutions, do not directly address many POs. However, there may be some specific courses like

Sustainability, Environment, and Communication that address specific POs. Projects and reports can potentially address many POs. But the POs addressed must get reflected in the rubrics used. Tagging a CO with a PO requires that the assessment includes items related to the identified PO. A CO of a course can potentially address more than one PO. However, it may not be possible to conduct instruction and assessment to address all the identified POs within the available time and resources. Assessment items related to some POs cannot be efficiently designed, and even if designed, cannot be used in centrally conducted and evaluated examinations. A Department can arrange for some activities outside the curriculum to address some POs. However, the scope and distribution of these activities need to be carefully planned by the Department.

A Course Outcome (CO), therefore, is to be tagged with POs, PSOs, Cognitive Level, Knowledge Categories, number of Classroom Sessions, and/or number of Laboratory/Field Trip hours. It will facilitate the computation of CO attainment and PO/PSO attainment as well.

A Course Outcome (CO) is to be tagged with POs, PSOs, Cognitive Level, Knowledge Categories, number of Classroom Sessions, and/or number of Laboratory/Field Trip hours.

Samples of courses, developed by participating faculty membersinworkshops,are given in the following. These are the first iterations. Teachers concerned with these courses can improve the COs and add or delete COs.

Course: Kinematics of Machines - Credits: 3:1:0

CO	Course Outcome	POs/ PSOs	CL	KC	Class Sessions	Tutorial (Hrs)
CO1	Illustrate the terminology of mechanisms	PO1/PSO 1	U	F	03	01
CO2	Identify the degrees of freedom and motion characteristics of planar mechanisms.	PO1/PSO 1	U	C, P	05	01
CO3	Predict the motion of planar mechanisms graphically and mathematically.	PO1/PSO 1	Ap	C, P	08	02
CO4	Determine the friction losses in bearings, and power transmitted in belt drives	PO1/PSO 2	Ap	P, FDP	08	02
CO5	Draw the profile of the cam for the desired follower motion.	PO1/PSO 1	Ap	P, C&S	07	03
CO6	Describe the characteristics of motion in gears with involute profile	PO1/PSO 1	U	C	04	01

CO7	Calculate the velocity ratio or the number of teeth for an epicyclic gear train drive.	PO1/PSO 1	Ap	P	03	02
Total Hours of Instruction					**38**	**12**

Course: Fluid Mechanics - Credits: 4:0:0

CO	Course Outcome	POs/ PSOs	CL	KC	Class Sessions
CO1	Understand the fundamentals of fluid mechanics and fluids	PO1, PSO1	U	C	6
CO2	Determine the basic equation to find the force on submerged surfaces	PO1, PSO1	Ap	C, P	9
CO3	Calculate the center of buoyancy of a floating body, and the velocity and acceleration of a fluid	PO1, PSO1	Ap	C	12
CO4	Calculate flow parameters using fluid flow meters and using dimension analysis to predict flow phenomena, viscous effects using Hagen Poiseille's equation	PO1, PSO1	Ap	C, P	12
CO5	Calculate functional losses through pipes and calculate the drag and lift, displacement, momentum, and energy thickness	PO1, PSO1	Ap	C, P	15
Total Hours of instruction					**54**

Analog Circuits and Systems - Credits: 3:0:1

CO	Course Outcome	POs/ PSOs	CL	KC	Class Sessions	Lab (Hrs)
CO1	Understand the characteristics of linear one-port and two-port signal processing networks	PO1, PO10, PSO1	U	F, C	3	
CO2	Model one-port devices including R, L, C and diodes, two-port networks, and active devices including amplifiers, Op Amps, comparators, multipliers, BJTs, and FETs	PO1, PO10, PSO1	U	C	9	4
CO3	Understand how negative and positive feedback influence the behaviour of analog circuits	PO1, PSO1	U	C	4	4
CO4	Design VCVS, CCVS, VCCS, CCCS, and DC and SMPS voltage regulators	PO3, PO4, PO5, PSO1	Ap	C, P, C&S, PC	10	4
CO5	Design analog filters	PO3, PO4, PO5, PSO1	Ap	C, P, C&S, PC	8	8
CO6	Design waveform generators, phase followers and frequency followers	PO3, PO4, PO5, PSO1	Ap	C, P, C&S, PC	6	8
Total Hours of instruction					**40**	**28**

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Annexure 1

Action Verbs associated with Revised 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

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

Apply

- Execute: Determine, calculate, compute, estimate, solve, use, draw, and conduct (a procedure in the known situation)
- Implementing: Determine, calculate, compute, estimate, solve, draw, and carry out (aprocedure in an 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/desig
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