Competencies

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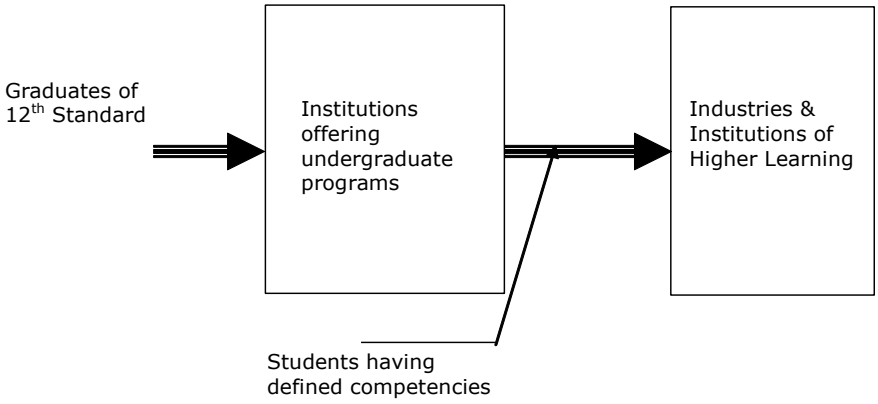
1. Introduction

When we teach we want our students to learn. Many terms are used to represent the outcomes of any learning. These include Outcomes, Learning Outcomes, Intended Learning Outcomes, Instructional Objectives, Educational Objectives, Behavioral Objectives, Performance Objectives, Terminal Objectives, Subordinate Skills, Subordinate Objectives, General Instructional Objectives, Specific Learning Outcomes, Competencies and Sub-competencies. We choose the word 'competency' to represent the outcome of learning because industry uses it, IMS Global has created the standard RDCEO (Reusable Definition of Competencies or Educational Objectives), and IEEE created the standard RCD (Reusable Competency Definition).

We formally define competency as the cluster of knowledge, skills, abilities, habits, character traits a person must have in order to perform a specific job well. It may also be defined as an effective ability, including attributes, skills and knowledge, to successfully carry out some activity which is totally identified.

The most important relationship for an institution of higher learning is



Industries and institutions of higher learning select students through testing their competencies. An organization assigns tasks, and builds project teams on the basis of competency profiles of their employees. The training of employees is decided on the competencies the employees are required to have for working on projects. Postgraduate programs are also planned to enable students to acquire higher level competencies. The competencies an engineering course should, therefore, be planned to meet the requirements of industries and institutions of higher learning. As many selections for employment and postgraduate programs are done through competitive examinations, they also provide basis for selecting the competencies for which the students need to be educated.

National Board of Accreditation (NBA), India, specifies Program Outcomes of engineering programs at undergraduate and post-graduate level. These are program non-specific. An Institution offering engineering degree programs may add up to four program outcomes specific to that program in addition to those specified by NBA. However, in view of the movement for creating approximate equivalence of undergraduate programs in Engineering across countries, an accord is signed in Washington, now known as Washington Accord. Program Outcomes identified by NBA are in the spirit of Program Outcomes identified by Washington Accord. The Program Outcomes as stated by NBA are given in Section 4.

The course competencies should be selected to be in alignment with Program Outcomes. As Program Outcomes are met through the courses of a program, each course aims to meet a subset of the Program Outcomes.

2. Types of competencies

Competencies can be

- Managerial
- Generic
- Technical/Functional

Managerial competencies include

- Strategic thinking and Scenario building
- Analysis
- Problem solving and Decision making
- Planning and Organizing
- Change management
- Managing small organizational groups
- Managing large organizational groups
- Team leadership
- Information management
- Innovation and Creation
- Mediation and Negotiation
- Mentoring and Coaching
- Facilitation and Group moderation
- Presentation and Public speaking
- Interviewing

Undergraduate engineering programs aim at meeting only a small subset of these competencies, that too slightly.

The **generic competencies** are important technical and non-technical abilities and skills for employment. These abilities and skills would be transferable to new situations. The generic competencies are also known as Soft Skills and Transferable Skills (Andreas Blom Hiroshi Saeki 2011). The Transferable Skills are further classified into Core Employability, Communication Skills, and Professional Skills. These are further elaborated as

Core Employability

- Reliability
- Self-motivated
- Willingness to learn
- Understand/take directions
- Integrity
- Teamwork

- Entrepreneurship
- Self-discipline
- Flexibility
- Empathy

Communication Skills

- Experiments/data analysis
- Reading
- Technical Skills
- Written Communication
- Verbal Communication
- Advanced computer
- Basic computer
- Communication in English

Professional Skills

- Problem solving
- Creativity
- Use of modern tools
- System design to needs

Technical competencies represent technical activities that a student should be able to perform at the end of a course or a program. They will be discipline specific

3. Course Competencies

Competencies represent what the students should be able to do at the end of a course as per the teacher. A course aims at facilitating the students to acquire some competencies as selected by the teacher. These competencies should be selected to meet a subset of Program Outcomes, proposed to be achieved by an engineering program. These competencies can be technical and/or generic and/or managerial. The number of competencies for a one-semester course is proposed to be 15 ± 5.

There are broadly two ways of writing competencies, one due to Mager (1997) and the other due to Gronlund (2007). Mager refers to competencies as Instructional Objectives and they have three elements: Performance, Conditions and Criterion. Gronlund also calls competencies as Instructional Objectives and they have only one element: Performance. Inclusion of Conditions and Criteria are optional. However, Gronlund associates two levels to Instructional Objectives: General Instructional Objectives and Specific Learning Outcomes.

The proposed structure of a competency statement is

Action: Represents the cognitive activity the learner should perform. An action is indicated by an action verb representing the concerned cognitive level (Create, Evaluate, Analyze, Apply, Understand and Remember).

Knowledge: Represents the specific knowledge from any one or more of the eight categories of knowledge including four general categories (Factual, Conceptual, Procedural and Metacognitive) and four categories specific to engineering (Vincenti) (Fundamental Design principles, Criteria and Specifications, Practical Constraints and Design Instrumentalities) of knowledge

Conditions: Represent the process(s) the learner is expected to follow or the conditions under which to perform the action. This is an optional element of competency statement.

Criteria: Represent the parameters that characterize the acceptability levels of performing the action. This is an optional element of competency statement.

Competencies are cognitive in nature and mainly discipline or subject specific. However, they can be stated to incorporate managerial and generic competency elements along with subject specific elements.

Sample Competencies

1. Determine the input-output characteristics of active two-port networks using Microcap simulator and TI Analog Laboratory unit and compare their characteristics as obtained by simulation and Lab Unit
    - Action: Determine(Apply)
    - Knowledge: input-output characteristics of active two-port networks (Conceptual)
    - Condition: using Microcap simulator and TI Analog Laboratory unit
    - Criteria: compare its characteristics as obtained by simulation and Lab Unit
2. Design analog multipliers and modulators as per given specifications.
    - Action: Design (Apply)
    - Knowledge: Procedural, and Criteria and Specifications
    - Condition: None
    - Criteria: None
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
    - Criteria: None
4. Calculate major and minor losses associated with pipe flow in piping networks
    a. Action: Calculate (Apply)
    b. Knowledge: major and minor losses associated with pipe flow in piping networks (Conceptual and Procedural)
    c. Condition: None
    d. Criteria: None
5. Estimate the conduction and switching power losses in power semiconductor switches including BJTs, MOSFETs and IGBTs.
    a. Action: Estimate (Apply)

b. Knowledge: Conduction switching power losses in power semiconductor switches (Procedural)
c. Condition: None
d. Criteria: None

4. Competencies and Program Outcomes

Every competency will meet one or more Program Outcomes, which are identified by National Board of Accreditation. All the competencies of a course together should meet the selected subset of Program Outcomes. Therefore, every competency should be written in a manner that clearly indicates the Program Outcomes it addresses.

Program Outcomes (NBA)

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 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 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, and 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 team work**: 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.

PO1. **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.

PO2. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Samples

1. Determine the changes effected by life on Earth on the cycling of chemicals in the air, water and soil.
   - Action: Determine (Apply)
   - Knowledge - the changes effected by life on Earth on the cycling of chemicals in the air, water and soil (Procedural)
   - Conditions: None
   - Criteria: None
   - Program Outcomes Addressed: PO1, PO10
2. Design analog filters as per specifications
   - Action: Design (Apply)
   - Knowledge: analog filters (Conceptual and Procedural)
   - Conditions: as per specifications
   - Criteria: None
   - Program Outcomes and the levels to which they are addressed: PO3, PO4, PO5

5. Check List for Competencies

Check the competencies and sub-competencies using the check list given in the following

1. Does the competency begin with an action verb (e.g., state, define, explain, calculate, determine, identify, select, plan, design etc.)?
2. Is the competency stated in terms of student performance (rather than teacher performance)?
3. Is the competency stated at the proper level of generality and relatively independent of other competencies (i.e., is it clear, concise, and readily definable)?
4. Do the competencies represent higher orders of learning (cognitive levels) adequately?
5. Are the competencies attainable (do they take into account students' background, prerequisite competences, facilities, time available and so on)?

6. Sample Competencies of an Engineering Course

Course: Analog Circuits

Competencies: At the end of the course the student should be able to

	Competency	**POs**
C1.	Understand the structure of present day electronic products	PO1
C2.	Identify analog signal conditioning and processing functions in instrumentation and control and communication.	PO1, PO2
C3.	Characterize linear one-port and two-port networks for their signal processing functions	PO1
C4.	Macro model Amplifiers, Op Amps, Comparators and Multipliers	PO1, PO2
C5.	Macro model BJT and FET	PO1, PO2
C6.	Understand how negative influence the behavior of the circuits using Op Amps, and positive feedback influences the behavior of circuits using Comparators	PO1, PO2
C7.	Design VCVS, VCCS, CCVS and CCCS as per specifications using Op Amps	PO1, PO2, PO3
C8.	Understand the concept of ideal filters and approximate mathematical representations of filters	PO1
C9.	Design first and second order passive filters	PO3
C10.	Design active filters using L-replacement, Q-enhancement (Sallen and Key) and Biquads (State-space)	PO3
C11.	Design active filters using 'switched capacitor filters'	PO3
C12.	Tune state-space filter using multiplier, DAcs and PLL method	PO2
C13.	Design amplitude stable and frequency stable tunable sinusoidal oscillators	PO3
C14.	Design amplitude stable and frequency stable tunable non-sinusoidal oscillators	PO3

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