Outcome-based Engineering Education need for Future Competent Engineers

Source : Ir. Academician Emeritus Professor Tan Sri Dato' Dr. HT Chuah
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Skills

The ability to do something well
Train a worker to do a particular tasks

21st Century Skills & Attributes

(1) Oral & Written (Communication Skills)
(2) Critical thinking/ Problem solving
(3) Collaboration across networks
(4) Curiosity in imagination
(5) Initiative and entrepreneurialism
(6) Hope and optimism
(7)Self-regulation
(8)Empathy and Global stewardship Resilience
(9)Grit
(10)Vision for the future

Top 10 Skills of 2025

Problem Solving

Self- Management

Working with People

Technology Use and Development

- **Analytical Thinking and Innovation**
- **Active Learning and Learning Strategies**
- **Complex Problem Solving**
- **Critical Thinking and Analysis**
- **Creativity, Originality and Initiative**
- **Leadership and Social Influence**
- **Technology Use, Monitoring and Control**
- **Technology Design and Programming**
- **Resilience, Stress Tolerance and Flexibility**
- **Reasoning, Problem Solving and Ideation**

Source: World Economic Forum 2020

Engineering Education

- **Strengthening of the Fundamentals**
- **Development of Analytical Mind**
- **Knowledge Exploration**
- **Self-Development and Life-long Learning**
- **Social Network Linkage**
- **Surviving Constraint Challenges**

Engineering Education

- **Deep Expertise in one's specialization**
- **Broad Knowledge across many domains – engineering, management, communications, leadership etc**
- **Collaboration with team members from diverse background**
- **Social Skills, Cultural Intelligence, Communication, Negotiation and other Life Skills**
- **Decision Making and Judgement**

The Origins of Outcome Based Education

- 5 Steps for Designing Curriculum by ***John Franklin Bobbitt (early 1900)***
- Basic Tasks of an Educator by ***Ralph Tyler (1949)***
- Outcome-Based Education (OBE) by ***William Spady (1988)***

Outcomes Based Engineering Education I: Theory and Practice in the Derivation of Outcomes" A European Historical Perspective

John Heywood (1997)
University of Dublin - Department of Teacher Education

"…It is concluded that there is no real difference between the objectives movement of yesterday and the "outcomes" movement of today."

Outcome-Based Education

- OBE is an educational philosophy that states education ought to aim at giving students a particular, minimum level of knowledge and abilities as the major educational outcomes

*"**OBE** is an educational process that involves **assessment and evaluation** practices to reflect the attainment of certain specified **outcomes (or attributes)** in terms of individual student learning. Once having decided what are the **key attributes or outcomes students should be able to do and master**, both **course structures and curricula** are designed to achieve those outcomes"*

Paradigm Shift in The Education Philosophy

From teacher-centre	→	To a student-centre
Traditional teaching: Teacher "owns" the knowledge and convey it to students	→	Modern teaching: Student (trainee) takes initiative to learn
Teacher brings the content and the answer into the training room	→	Teacher as a facilitator who asks questions and provides guidelines for the acquisition of knowledge

Requirements for the Students

- ✓ **Active role** – must come prepared for each class; contribute by teaching others, actively participating, taking risks, learning from instructor or classmates

- ✓ **Ethics** – respect, trust and openness

- ✓ **Committed to learning** – continual improvement

Instructors/Supervisors

- Pedagogical skills
- Scientific skills
- Time management
- Project based on staff research

Outcome-Based Education

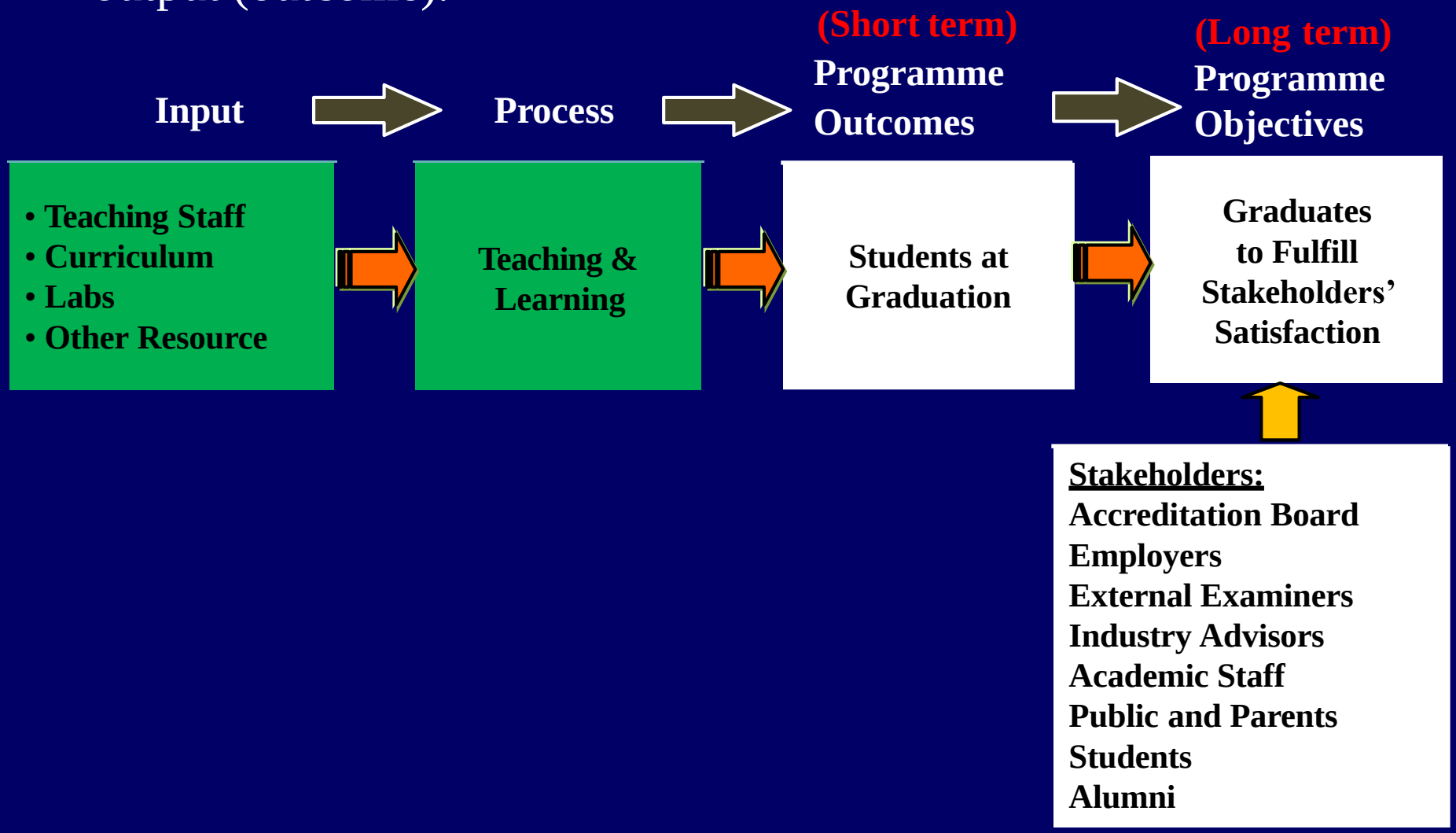
OBE develops:

- Lifelong Learner
- A knowledgeable person with deep understanding
- Complex Thinker
- Creative Person

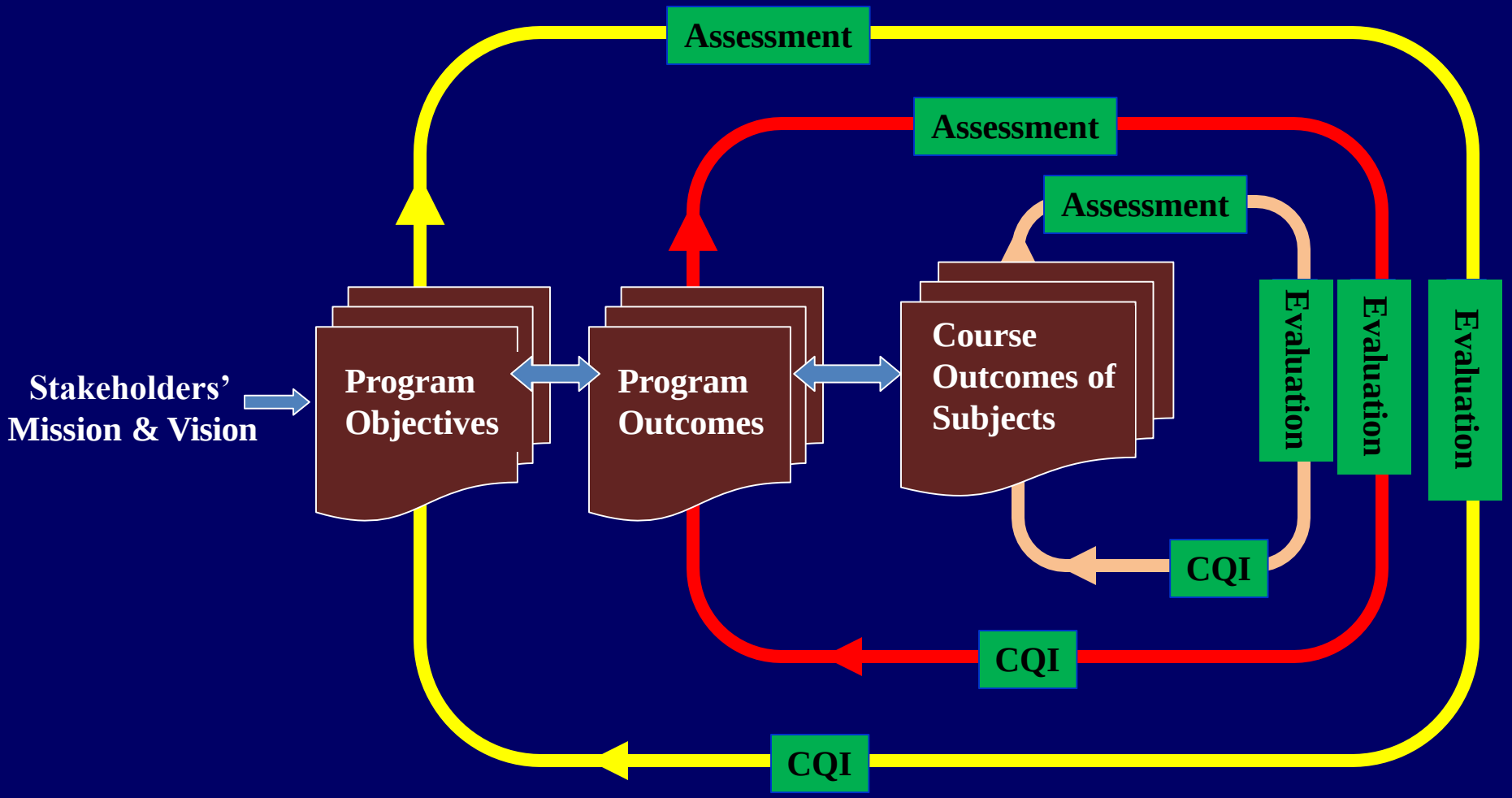
- Active Investigator
- Effective Communicator
- Participant in an Interdependent World
- Reflective and Self-Directed Learner

Outcome-Based Education

- Shifting from measuring input and process to include measuring the output (outcome).



Outcome-Based Education



Characteristics of OBE curricula

1. It has programme education objectives (PEOs), programme outcomes (POs), course learning outcomes or unit learning outcome (ULO/CO) and **performance indicators**

2. It is objective and outcome driven, where every stated objective and outcomes can be **assessed and evaluated**

3. It is centered around the needs of the students and the **stakeholders** (example: Internal : teacher, student and university; External : employer, alumni, Regulatory body)

4. Every learning outcome is **intentional** and therefore the outcomes must be assessed using suitable performance indicators.

PEO Assessment Indicator

Characteristics of OBE curricula (Cont'd)

5. Programme objectives (PEO) address the graduates attainment a few years (say **5 years)** after their graduation.

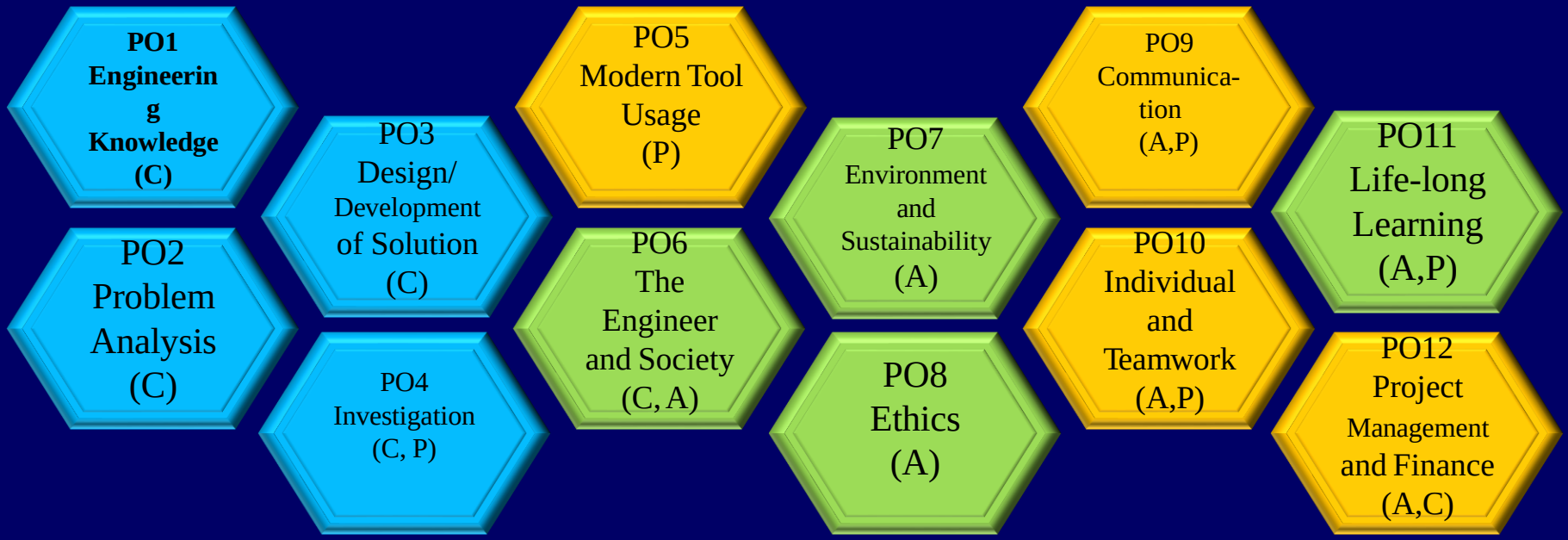
PEO	Domain	Performance Indicator	Achievement Criteria	Performance Target
PEO 1	Technical Competence	1) Functional Position 2) Annual Income 3) Number of Project Involved	A scale of 1 -5 is used for evaluation of each performance indicator. The achievement percentage is calculated based on average score over maximum score of 5.	50%
PEO 2	1) Communication 2) Leadership	1) Recognition for communication proficiency 2)Position in an engineering project involved		1) 60% 2) 30%
PEO 3	Professionalism / Lifelong Learning	1) Professional membership 2) Postgraduate degree 3) Professional / technical development		50%

Characteristics of OBE curricula (Cont'd)

6. Programme outcomes, which consist of **abilities** to be attained by students before they graduate are formulated based on the programme objectives.

PO

Program Outcomes are what the students should have achieved by graduation time: address Cognitive (C), Psychomotor(P), and Affective (A) domains to be attained by students



Characteristics of OBE curricula (Cont'd)

7. Programme outcomes address **Knowledge, Skills and Attitudes** to be attained by students

Cognitive Domain (thinking, knowledge)	Psychomotor Domain (doing, skills)	Affective Domain (feeling, attitudes)

8. Course outcomes (COs) must satisfy the stated programme outcomes. There is **no need** for **ANY(individual)** course to address all programme outcomes

9. Teaching or Learning method may have to be **integrated** to include **different delivery methods** to complement the traditional Lecture method.

Course Development

This covers

- Content - typical topics in the subject matters
- Subject Topics - teaching plan
- Course Outcomes - group of learning (topic) outcomes
- Course Outcomes to Programme Outcomes linkage

Considerations of:

- **Depth – e.g. Bloom's taxonomy**
- **Delivery and assessment**
- **Students' time and competencies covered**

Creating a Course

Planning

- Identifying course content and defining measureable learning outcomes

Instruction

- Select and implement methods – deliver the specified content and facilitate student achievement of the outcomes

Assessment and Evaluation

- Select and implement methods – determine how well the outcomes have been achieved

Course Outcomes are essential as they:

- define the breadth and depth of learning that students are expected to achieve
- provide a benchmark for formative and summative, assessment
- clearly inform expectations to students
- clearly communicate graduates' skills to the stakeholders
- define coherent units of learning that can be further subdivided for classroom or other delivery modes
- guide and organize the lecturer and the student

3 Essential Components of a Course Outcome:

1. Action verb (V): Describe behavioural action

2. Condition (C): Context under the behaviour is to happen

3. Standard (S) : Criteria of acceptable level of performance

3 Essential Components of a Course Outcome:

1. Action verb (V)

- Well-written verbs must be (SMART), i.e. observable:

Specific, Measurable, Achievable, Realistic, Time Frame

- Try to avoid using these (not observable):

appreciate, aware, familiar, know, learn, understand

Example 1:

- describe the principles used in designing Z (V)

Example 2:

- design a column (V)

3 Essential Components of a Course Outcome:

2. Condition (C)

Example 1:

- describe the principles used in designing Z (V)
- orally describe the principles used in designing Z. (V&C)

Example 2:

- design a column (V)
- design a column using Microsoft X design template (V&C)

3 Essential Components of a Course Outcome:

3. Standard (S)

Example 1:

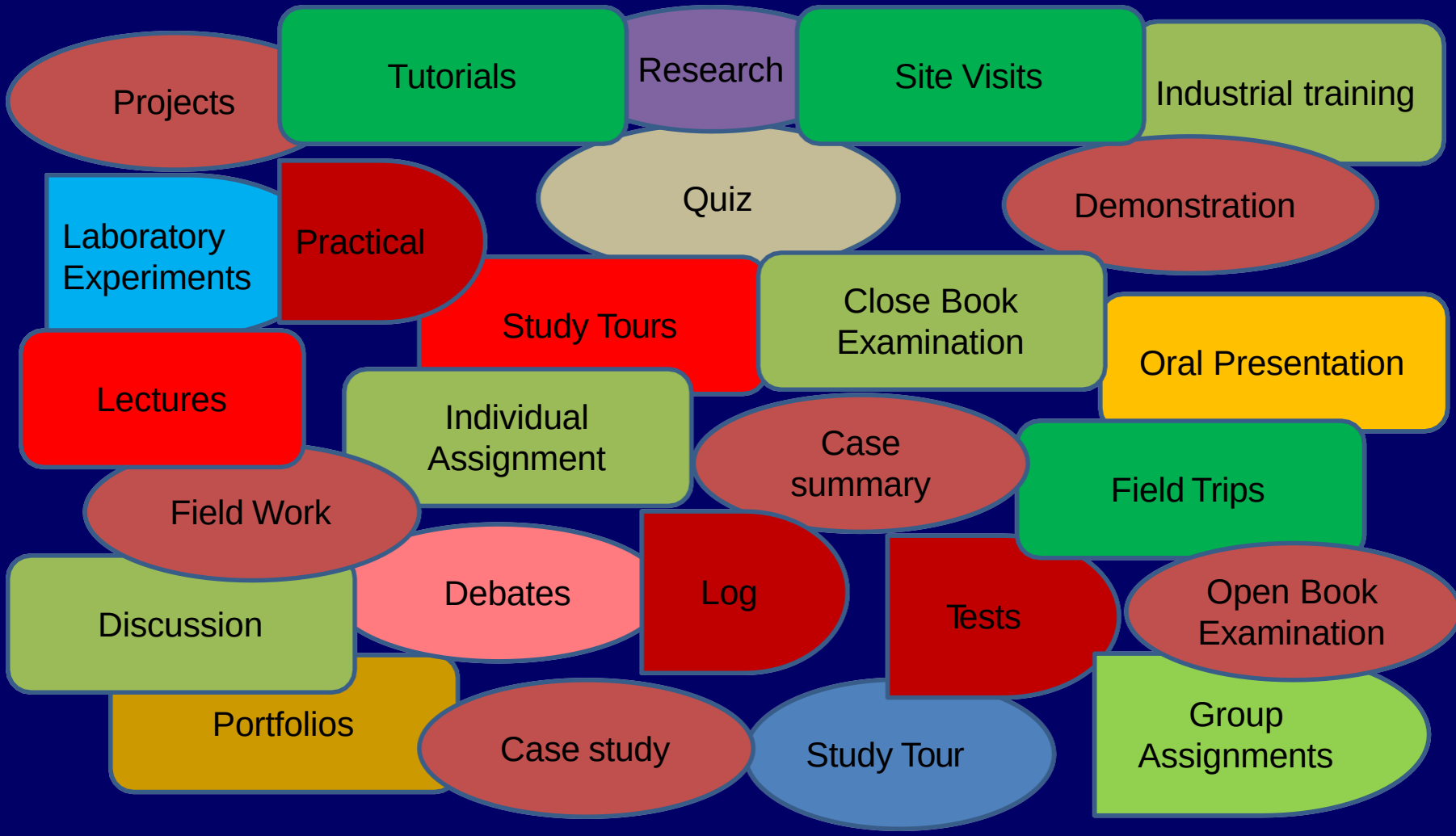
- describe the principles used in designing Z (V)
- orally describe the principles used in designing Z (V&C)
- orally describe the four principles used in designing Z (V & C & S)

Example 2:

- design a column (V)
- design a column using Microsoft X design template (V&C)
- design a column using Microsoft X design template based on BS 5950:Part 2 (V & C & S)

Outcome-Based Education

*Types of Teaching/Learning Delivery Activities**

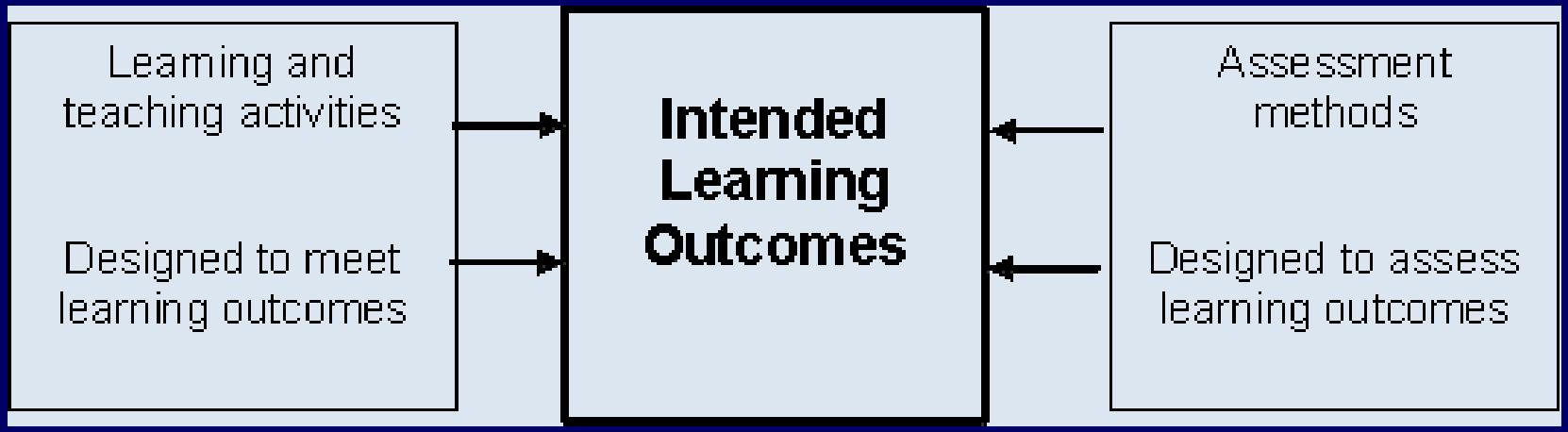


**Any assessment of learning activities and outcomes must come with systematic assessing criteria and marking scheme*

Outcome-Based Education

Delivery & Assessment

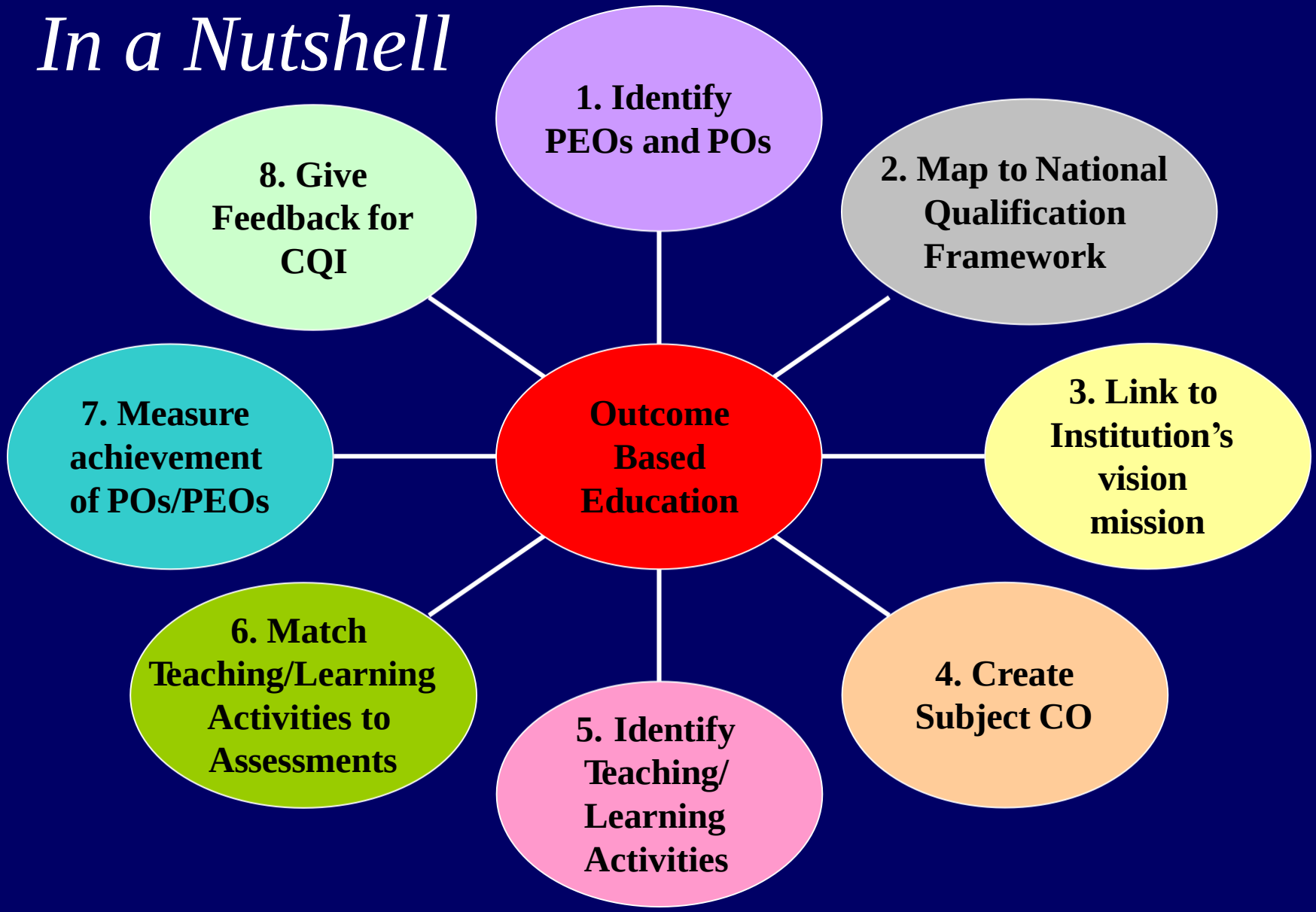
Aligning *course outcomes, learning and teaching activities and the assessment*



Adapted from Biggs, 1999 p. 27

Outcome -Based Education

In a Nutshell



Essentials Components of OBE

- ✓ Effective Programme Education Objectives (PEOs)
- ✓ Effective Programme Outcomes (POs)
- ✓ Well Defined and Aligned Course Outcomes (COs)
- ✓ Practical Assessment Tools
- ✓ Effective Assessment Planning and Execution
- ✓ Robust Evaluation Planning and Execution
- ✓ Continuous Quality Improvement (CQI) procedures and actions

Management Driven! Management Commitment!

Expected Changes to Implement OBE:

Curriculum/Course Content Revision - Reviewing course content to suit specified Course and Programme Outcomes, industrial needs, job specifications, professional body requirement (accreditation), own niche, etc.

- The academic curriculum and curricular design shall strongly reflect the philosophy and approach adopted in the *programme structure*, and the choice of the teaching-learning (*delivery*) and *assessment methods*.

- A balanced curriculum shall include all *technical and non-technical attributes* listed in the GAs, and shall be a balance between the essential elements forming the *core* of the programme and additional specialist or optional studies (*electives*).

Expected Changes to Implement OBE: (Cont'd)

- **General Education Components**

1. Mathematics
2. Computing
3. Languages
4. General studies
5. Co-curriculum
6. Management
7. Law
8. Accountancy
9. Economics
10. Social Sciences, etc.

Expected Changes to Implement OBE: Cont'd.

Curriculum Review

There must be a review of engineering curriculum to emphasise on:

1. Sustainability and Environmental Friendliness
2. Ethics and Professionalism
3. Soft-skills (Communications/Language/Emotional Intelligence/Cultural Intelligence/Negotiation/Cognitive Flexibility)
4. Life-Long Learning
5. Project Management
6. Finance, Economics and Accountancy
7. Related Laws (Land Law/Contract Law/By-laws)
8. Complex Problem

Expected Changes to Implement OBE: Cont'd.

Innovative/Flexible Delivery/Teaching-Learning Methods - Introducing innovative/flexible teaching methods/delivery tools to develop and achieve POs and PEOs in students/graduates

Variety of Assessment & Evaluation Tools - Introducing variety of assessment and evaluation tools to measure the achievement of POs and PEOs

Data & Evidence Collection - Collecting evidences of process involved and the achievement of the POs and PEOs

Continuous Quality Improvement (CQI) - Closing the loop

In Line with UN Sustainable Development Goals

Goal 1: No Poverty
Goal 2: Zero Hunger
Goal 3: Good Health and Well Being
Goal 4: Quality Education
Goal 5: Gender Equality
Goal 6: Clean Water and Sanitation
Goal 7: Affordable and Clean Energy
Goal 8: Decent Work and Economic Growth
Goal 9: Industry, Innovation and Infrastructure

via Best Practices in Engineering Profession/Projects, and Innovative Engineering Solutions

In Line with UN Sustainable Development Goals

Goal 10: Reduced Inequalities
Goal 11: Sustainable Cities and Community
Goal 12: Responsible Consumption and Production
Goal 13: Climate Action
Goal 14: Life Below Water
Goal 15: Life on Land
Goal 16: Peace, Justice and Strong Institutions
Goal 17: Partnerships for the Goals

via Best Practices in Engineering Profession/Projects, and Innovative Engineering Solutions,
Mobility of Engineering Personnel for Development and Smart Partnership

Complex Problem

Need to think broadly and systematically and **see the big picture**

Complex Problem

Difficult Decision

Uncertain Strategy

Confusing Idea

Contentious Product

Intractable Change

How are UN Sustainable Development Goals integrated into the curriculum?

- Final Year Project – Real-life *Problem Solving*
- Industrial Placement
- Design Project – Real-life *Engineering Activities*
- General Courses
  - Core & Specialist (Engineering) Courses
  - Elective Courses

with Open-ended Questions and Assignment, CEA

Some Lessons learnt from Accreditation Activities

- Does not know the Teaching Plan
- Done without Referring to the Plan
- Does not know How to Translate Plan into Assessment
- Assessing at Low-Medium level (not Challenging)
- No Feedback to Students except at the End of Semester
- Does not know How to Relate Assessment to Expected Outcomes
- Traditional Assessment
- Non-Technical Skills neglected

Curriculum Review (1/3)

- **Solid Fundamental of Engineering Sciences in First 2 Years of the Programmes: Mathematics, Material Sciences, Electromagnetics, Thermodynamics, Dynamics and Kinetics etc.**
- **In First 2 years, while training students on basics, more engineering application examples be incorporated in lectures. More open ended assignment and projects related to everyday life to be introduced**
- **More elective options for students (flexible for Faculty to introduce, to review, to remove) in 3rd and 4th Year as and when technology changes**
- **Promote exchange of students internationally on credit transfer basis**

Curriculum Review (2/3)

There must be a review of engineering curriculum to emphasise on:

1. Sustainability and Environmental Friendliness
2. **Ethics and Professionalism**
3. Soft-skills (Communications/Language/Emotional Intelligence/Cultural Intelligence/Negotiation/Cognitive Flexibility)
4. **Life-Long Learning**
5. Project Management
6. **Finance, Economics and Accountancy**
7. Related Laws (Land Law/Contract Law/By-laws)
8. **Innovative Solutions to Industry- related/Real-Life Problem**

Curriculum Review (3/3)

- **Work with Industry Players to give exposure and real life application examples in lectures/assignment and site visits**
- **Allow peer teaching in tutorials and laboratory sessions – the best test of own's knowledge and understanding**
- **Students must be trained to be independent, decisive, team players and be life-long learners, with high ethical values and social responsibility**

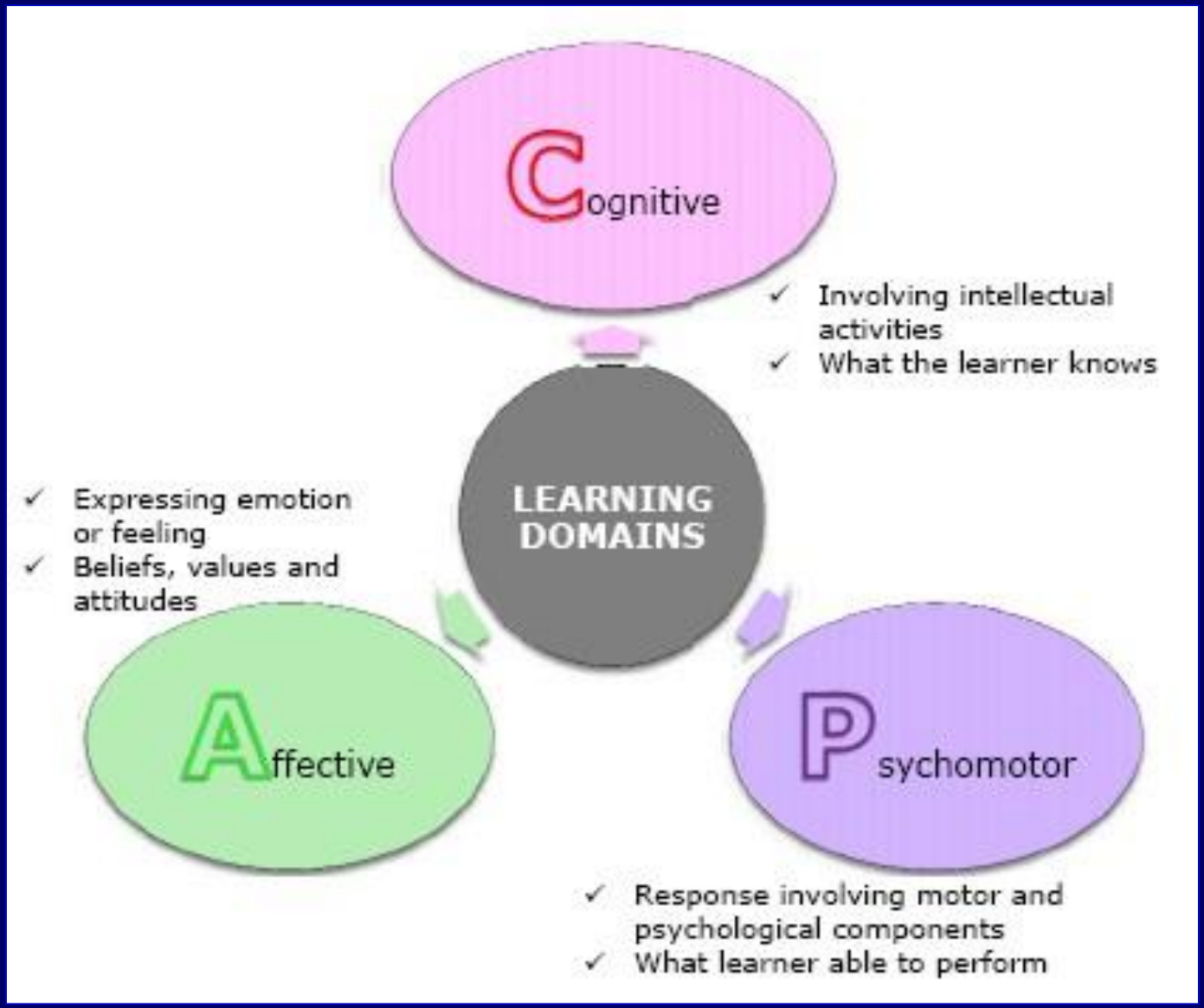
How are Complexity and UN Sustainable Development Goals integrated into the curriculum?

- General Courses
  - Core & Specialist (Engineering) Courses
  - Course on relevant Environmental Laws, Sustainable Development, Renewable Energy
  - Elective Courses

  with Open-ended Questions and Assignment dealing with SDG's
- Industrial Placement – Students are reminded on the implementation of SDG's
- Design Project – Real-life *Complex Engineering Activities* – SDG's are highlighted

ENGINEERING EDUCATION
and
BLOOM'S TAXONOMY

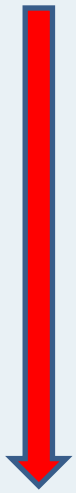
BLOOM'S TAXONOMY: 3 Domains



Introducing the Knowledge Classification by Using Bloom's Taxonomy

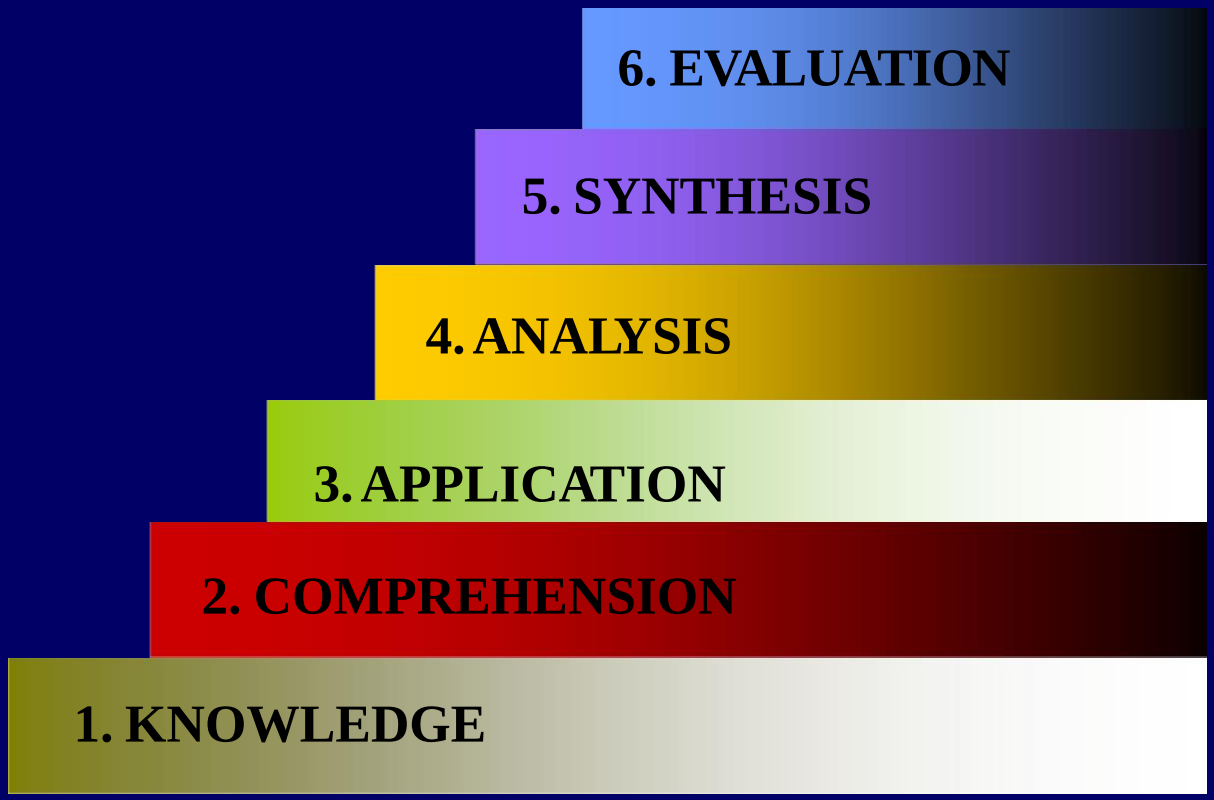
Cognitive Domain of Learning	The cognitive domain explained earlier is redefined as the intersection of: 1. The Knowledge Classification [Four Types: R1: Factual, R2: Conceptual, R3: Procedural, R4: Metacognitive] 2. The Cognitive Process Dimension [Six Types: L1: Remember, L2: Understand, L3: Apply, L4: Analyze, L5: Evaluate, L6: Create]

The Knowledge Classification: Classifies Four types of knowledge that Learners may be expected to acquire

Concrete Knowledge  Abstract Knowledge	R1. Factual Knowledge	The basic elements a student must know to be acquainted with a discipline (e.g., knowledge of terminology, knowledge of specific details and elements)- Basic Knowledge on Facts
	R2. Conceptual Knowledge	The inter-relationships among the basic elements within a larger structure that enable them to function together (e.g., knowledge of classification, knowledge of theories, models and structures, knowledge of principles and generalizations)- Interrelations Between Facts
	R3. Procedural Knowledge	Knowledge of subject specific skills and algorithms, knowledge of specific techniques and methods; knowledge of criteria for determining when to use appropriate procedures-How to Make Use of Factual and Conceptual Knowledge
	R4. Meta-cognitive Knowledge	Knowledge of cognitive task in general as well as awareness of one's own cognition; Self knowledge-Realizing that you know an answer to a question but simply cannot recall it at the moment

Cognitive Domain Categories

- Knowledge and the development of intellectual skills
- Includes the recall or recognition of specific facts, procedural patterns, and concepts

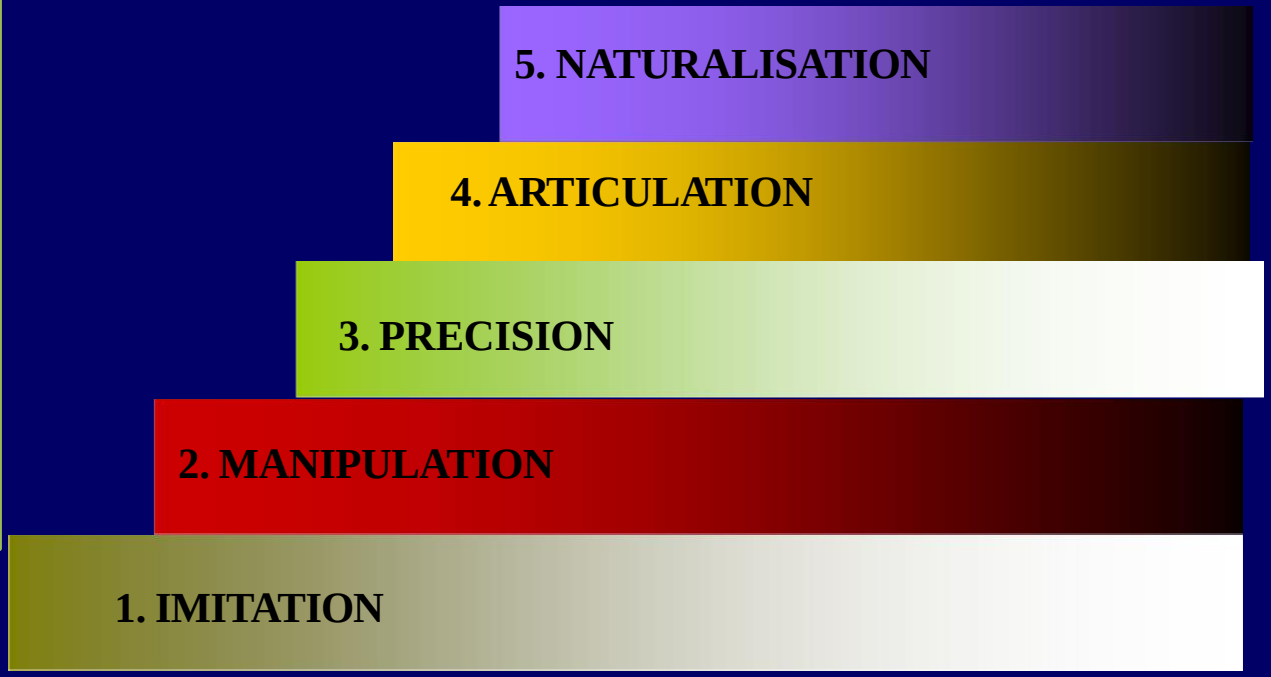


Affective Domain Categories

- Describes the way people react <u>emotionally</u> and their ability to feel another living thing's pain or joy.
- Typically targets the awareness and growth in attitudes, emotion, and feelings.

Psychomotor Domain Categories

- Describe the ability to physically manipulate a tool or instrument
- Usually focus on change and/or development in behavior and/or skills



Bloom's Learning Taxonomy

Cognitive Levels 1-6	Affective Levels 1-5	Psychomotor Levels 1-5
Knowledge-based	**Attitude-based**	**Skills-based**
1. Remembering (*recall data*)	1. Receiving phenomena (*aware of phenomena*)	1. Imitating (*copy as a novice*)
2. Understanding (*comprehend, explain*)	2. Responding (*react to phenomena*)	2. Manipulating (*follow instructions*)
3. Applying (*use, practise, apply*)	3. Valuing (*understand and act*)	3. Developing precision (*perform task*)
4. Analysing (*make sense of structure*)	4. Organising personal value system (*respond, reflect*)	4. Articulating (*combine/integrate skills*)
5. Evaluating (*assess, judge, compare*)	5. Internalising value system (*adopt behaviour as habitual*)	5. Naturalising (*automate, become expert*)
6. Creating (*synthesise, design, build*)		

Thank you for your Attention.