

# ENGINEERING GRADUATE ATTRIBUTES AND MAPPING OF OUTCOMES



A WORKSHOP FOR PROGRAMME EVALUATORS OF OUTCOME-BASED  
ENGINEERING ACCREDITATION

BY

ENGINEERING ACCREDITATION COMMITTEE  
COUNCIL FOR THE REGULATION OF ENGINEERING IN NIGERIA (COREN)

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# Outcomes of the Workshop

At the end of this workshop, participants are expected to:

1. explain different engineering graduate attributes and their importance
2. comprehend the engineering
  - knowledge attribute profile
  - complex problem-solving profile
  - complex activities profile
3. able to map POs to PEOs, Courses to POs and CLOs to POs.

# Outline of the Workshop

Engineering Graduate Attributes and their Importance

Highlights of

- knowledge attribute profile

- complex problem-solving profile

- complex activities profile

Mappings: POs to PEOs, Courses to Pos, and CLOs to POs

**SECTION A:  
ENGINEERING GRADUATE ATTRIBUTES**

# ENGINEERING GRADUATE ATTRIBUTES

Emphasis on engineering applications in degree Programmes is aimed at ensuring that all engineering graduates have a sound understanding of **up-to-date industrial practice**.

Examples of Graduate Attributes for specific disciplines:

# ENGINEERING GRADUATE ATTRIBUTES...

Graduates of Civil Engineering are expected to :

1. appreciate the characteristics and structural behaviour of materials in a variety of user environments.
2. be able to analyze and design structural components from these materials.
3. appreciate the range of construction technology currently available and the skills which they require in people for their use.
4. appreciate the cost aspects of material selection, construction methods, operation and maintenance in their interaction with design and the delivery of civil engineering facilities and services.
5. understand the whole process of industrial decision-making in design, manufacturing and use and how it is influenced not only by technical ideas but also by the practical constraints of financial and human resources as well as the business and social environment of engineering.

# ENGINEERING GRADUATE ATTRIBUTES...

Graduates of Mechanical Engineering are expected to:

1. appreciate the characteristic behaviour of materials in a variety of user environments.
2. appreciate the range of manufacturing systems and industry energy currently available and the skills which they require in people for their use.
3. appreciate the cost aspects of material selection, manufacturing methods, operation and maintenance in their interaction with design and product.
4. understand the whole process of industrial decision-making in design, manufacturing and use and how it is influenced not only by technical ideas but also by the practical constraints of financial and human resources as well as the business and social environment of engineering.

# ENGINEERING GRADUATE ATTRIBUTES...

Graduates of **Electrical and Electronic** Engineering are expected to:

1. appreciate the characteristic behaviour of materials in electrical and electronic systems.
2. be able to analyse and design electrical and electronic systems from devices/components made of various materials.
3. understand the concepts of generation, transmission and distribution of low and high voltage power.
4. appreciate cost effectiveness and energy consumption of component/device equipment selection, manufacturing process and integration process.
5. appreciate the range of manufacturing methods currently available and the skills which they require in people for their use.
6. understand the whole process of industrial decision making in design, manufacturing and use and how it is influenced not only by technical ideas but also by the practical constraints of financial and human resources and by the business and social environment of engineering.

# ENGINEERING GRADUATE ATTRIBUTES...

Graduates of Chemical Engineering are expected to:

1. appreciate the physical/chemical characteristics and properties of materials.
2. be able to adopt these materials in process design and analysis.
3. calculate and analyze the material and energy flows for a given chemical process.
4. understand the general sequence of processing steps for any given type of chemical process.
5. understand the selection or estimation of process operating conditions, selection of process equipment, maintenance and process troubleshooting.
6. analyze the various types of unit operations and processing steps and to decide their relative advantages or disadvantages on the basis of environment, economics, safety and operability.
7. understand the various process control schemes for the purpose of maintaining production quality, ensuring process safety and preventing waste.

An Engineering programme which targets to develop these attributes in its graduates must ensure that its curriculum encompasses all the desired elements of ***Knowledge Profile, Complex Problem Solving and Complex Engineering Activities***

# International Engineering Alliance Requirements of Different Accords

<b>Washington Accord (WA) Complex Problems</b>	<b>Sydney Accord (SA) Broadly Defined Problems</b>	<b>Dublin Accord (DA) Well defined Problems</b>
Requires in-depth knowledge that allows a fundamentals-based first principles analytical approach.	Requires knowledge of principles and applied procedures or methodologies.	Can be solved using limited theoretical knowledge, but normally requires extensive practical knowledge.

Washington Accord → Engineers

Sydney Accord → Engineering Technologists

Dublin Accord → Engineering Technicians



# Knowledge Attribute Profile

S/No.	Attribute
K1	A systematic, theory-based understanding of the <b>natural sciences</b> applicable to the discipline.
K2	Conceptually-based <b>mathematics</b> , numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline.
K3	A systematic, theory-based formulation of <b>engineering fundamentals</b> required in the engineering discipline.
K4	Engineering <b>specialist knowledge</b> that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.

# Knowledge Attribute Profile ....

S/No.	Attribute
K5	Knowledge that supports <b>engineering design</b> in a practice area.
K6	Knowledge of <b>engineering practice</b> (technology) in the practice areas in the engineering discipline.
K7	<b>Comprehension</b> of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability.
K8	Engagement with selected knowledge in the <b>research literature</b> of the discipline.

# Complex problems (A requirement of W.A)

1. Involve wide-ranging or conflicting technical, engineering and other issues
2. Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models
3. Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach
4. Not frequently encountered issues
5. Are outside problems encompassed by standards and codes of practice for professional engineering
6. Involve diverse groups of stakeholders with widely varying needs
7. Have significant consequences in a range of contexts
8. Are high level problems including many component parts or sub-problems

# Attributes of Complex Problem Solving

	<b>Attribute</b>	
	Preamble	Engineering problems which cannot be resolved without in-depth engineering knowledge, and have some or all of the characteristics listed below:
1.	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.
2.	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.
3.	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.

# Range of Complex Problem Solving ....

	<b>Attribute</b>	
4.	Familiarity of issues	Involve infrequently encountered issues
5.	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.
6.	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.
7.	Consequences	Have significant consequences in a range of contexts.
8.	Interdependence	Are high level problems including many component parts or sub-problems.

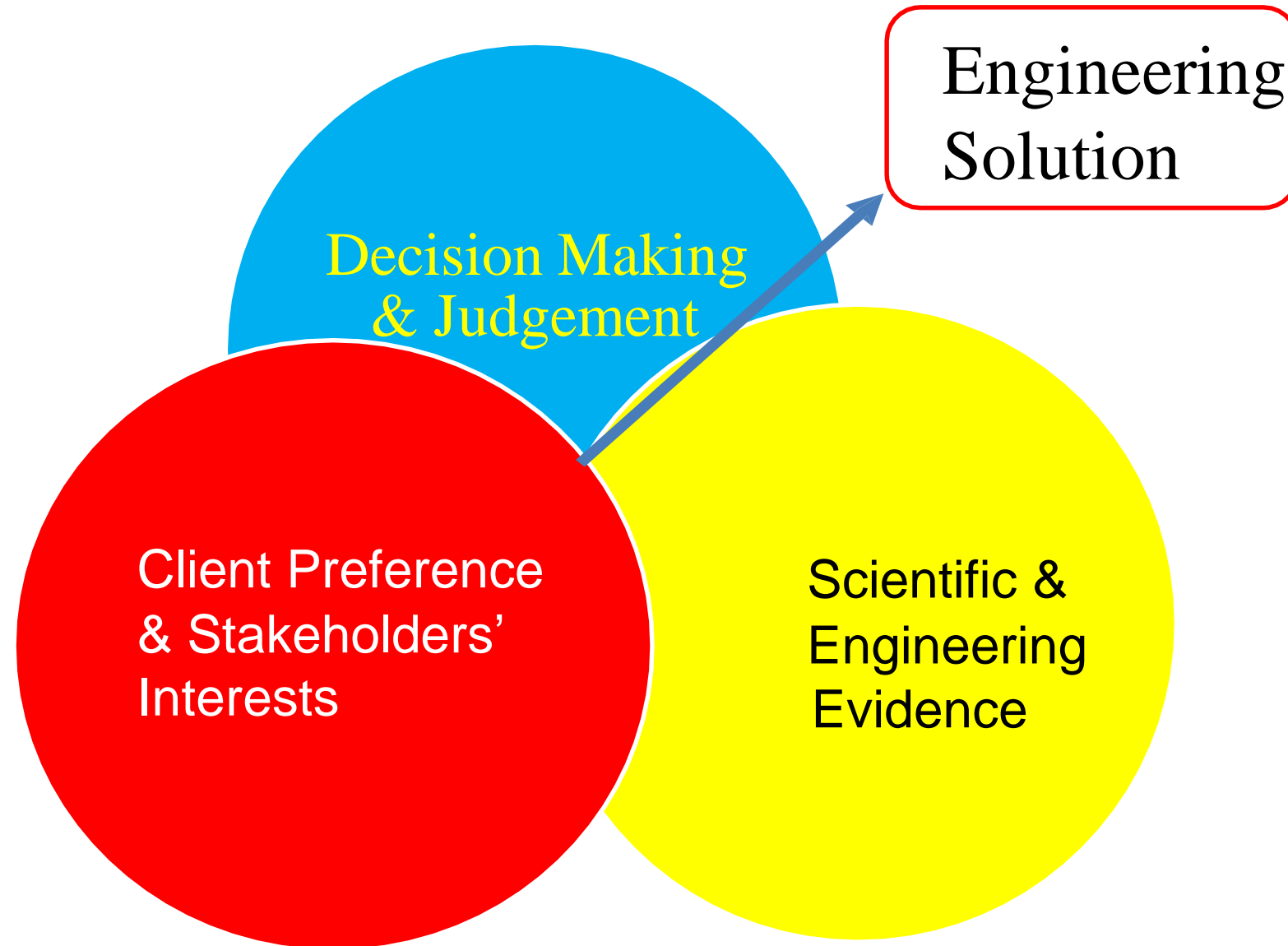
# Attributes of Complex Engineering Activities

	<b>Attribute</b>	
	Preamble	Complex activities means (engineering) activities or projects that have some or all of the following characteristics listed below:
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).
2	Level of interaction	Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues.

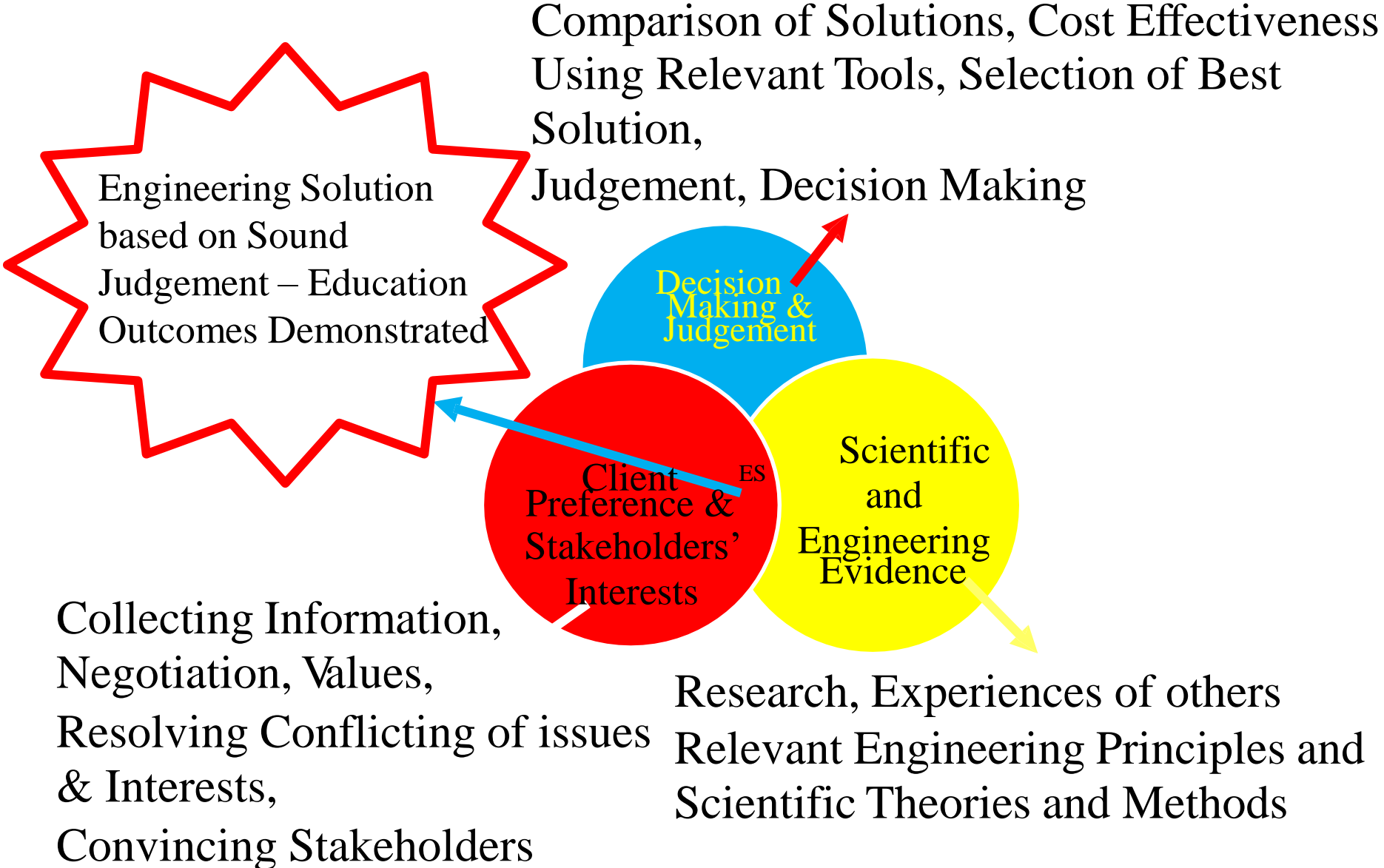
# Range of Complex Engineering Activities....

	<b>Attribute</b>	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.

# Solution for a Complex Engineering Problem



# Engineering Solution



# 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**

# Characteristics of Problems

## Technical Problems

- Isolatable boundable problem
- Universally similar type
- Stable and/or predictable problem parameters
- Multiple low-risk experiments are possible
- Limited set of alternative solutions
- Involve few or homogeneous stakeholders
- Single optimal and testable solutions
- Single optimal solution can be clearly recognised

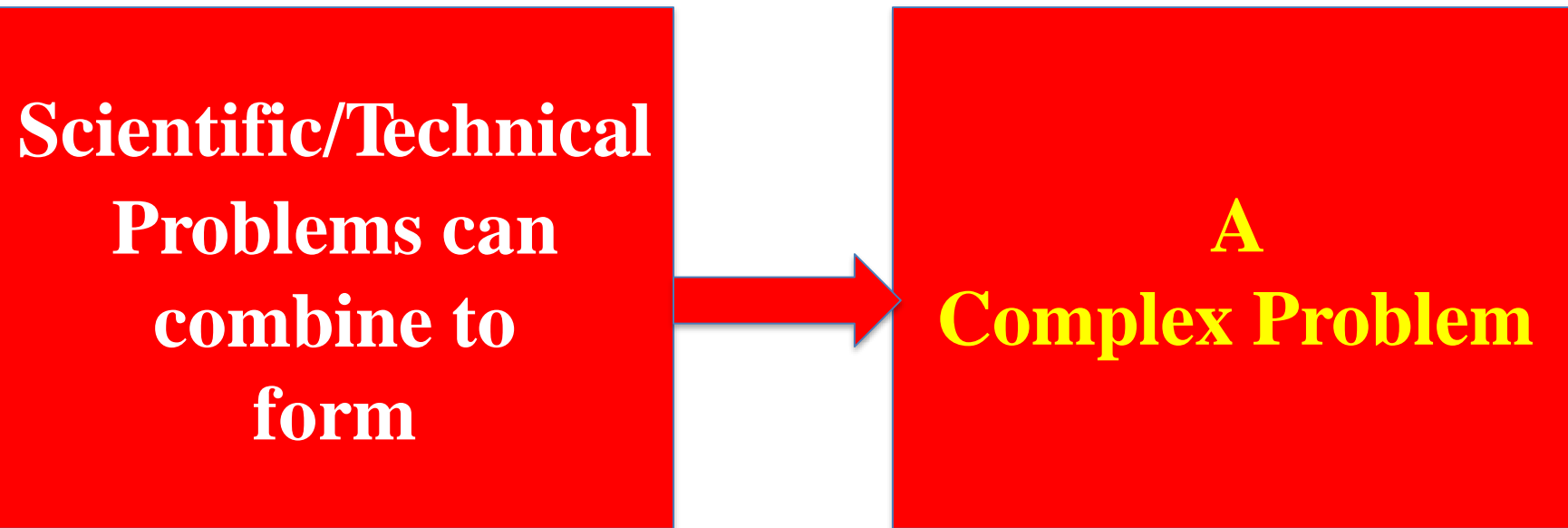
## Complex Problems

- No definitive problem boundary
- Relatively unique or unprecedented
- Unstable and/or unpredictable problem parameters
- Multiple experiments are not possible
- No bounded set of alternative solutions
- Multiple stakeholders with different views or interest
- No single optimal and/or objectively testable solution
- No clear stopping point

# How is Complexity Integrated into the Curriculum?

- Final Year Project – Real-life *Complex Problem Solving*
- Industrial Placement
- Design Project – Real-life *Complex Engineering Activities*
- General Courses
  - Core & Specialist (Engineering) Courses
  - Elective Courses*with Open-ended Questions and Assignment*

# Complex Problem



# Complex Problems (*Need High Taxonomy Level*)

*Complex Engineering Problems have characteristic WP1 and some or all of WP2 to WP7, EP1 and EP2, that can be resolved with in-depth forefront knowledge*

WP1	Depth of Knowledge required	Resolved with <b>forefront in-depth</b> engineering knowledge (WK3, WK4, WK5, WK6 or WK8) which allows a fundamentals-based, first principles analytical approach
WP2	Range of conflicting requirements	Involve <b>wide-ranging or conflicting</b> technical, engineering and other issues
WP3	Depth of analysis required	Have <b>no obvious solution</b> and require abstract thinking, originality in analysis to formulate suitable models.
WP4	Familiarity of issues	Involve <b>infrequently encountered</b> issues
WP5	Extent of applicable codes	<b>Beyond codes</b> of practice
WP6	Extent of stakeholder involvement and level of conflicting requirements	Involve <b>diverse groups of stakeholders</b> with widely <b>varying needs</b> .
WP7	Interdependence	Are <b>high level problems</b> including <b>many component</b> parts or sub-problems
EP1	Consequences	Have <b>significant consequences</b> in a range of contexts.
EP2	Judgement	Require judgement in <b>decision</b> making

**Annex B-1: Mapping of POs to PEOs (Sec 3.2.2)**

<b>COREN Programme Outcomes (as defined in Sec 3.2.2)</b>	<b>PEO 1</b>	<b>PEO 2</b>	<b>PEO 3</b>	<b>PEO 4</b>
PO1				
PO2				

# Annex B-2: Mapping of CLOs to POs (Sec 3.2.2)

Course Learning Outcomes (as defined by the Programme)	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
	POs as defined by COREN (more may be added by the Programme)											

**Annex B-3: Course Evaluation Form**  
**Page 99 of the COREN ACCREDITATION MANUAL**

# Mapping

1. Mapping is a matrix that visually represents the alignment between programme goals with programme objectives and outcomes.
2. It allows the department to identify which courses address each of the learning outcomes
3. Improves curriculum alignment and assists with curriculum maps.
4. It is used to explore how students are meeting programme-level outcomes at the course level.
5. Outcomes mapping focuses on student learning.
6. Allows departments to ensure that the entire curriculum offers students sufficient opportunity to develop the knowledge and skills associated with each of its outcomes.



Course Outcomes

CO	Description
CO-01	Identify the different units of microprocessor, and distinguish between different types of microprocessors. [E]
CO-02	Identify the internal architecture of 8088/8086 microprocessors, including the internal registers. [E]
CO-03	Differentiate between different instruction formats and addressing modes of the 8088/8086 microprocessors. [E]
CO-04	Familiar with the instruction set of the 8086/8088 microprocessor, including the data transfer, logic and arithmetic instructions, as well as the shift and rotate instructions. [E]
CO-05	Implement PUSH & POP operations in the stack, and conduct direct memory access. [E]
CO-06	Carry out appropriate procedure for subroutines operations in the microprocessor. [E]
CO-07	Familiar with the 8086/8088 hardware organization of the memory, their I/O and memory interfaces. [E]
CO-08	Familiar with the interrupt topics: interrupts, registers, and instructions etc. [E]

PO	Description
<i>A</i>	Ability to apply knowledge of mathematics, statistics, science and engineering principles. The mathematics knowledge includes linear algebra, vector algebra, partial differential equations, complex analysis, and probability and random processes
<i>B</i>	Ability to design and conduct experiments safely, as well as to analyze and interpret data
<i>C</i>	Ability to design electrical components, systems or processes to meet desired specifications with realistic constraints such as economic, environmental, social, political, ethical, health, safety, manufacturability, and sustainability
<i>D</i>	Ability to work in teams including multidisciplinary teams
<i>E</i>	Ability to identify, formulate and solve problems encountered in the practice of electrical engineering
<i>F</i>	Understanding of professional and ethical responsibility
<i>G</i>	Ability to communicate effectively orally and in writing
<i>H</i>	The ability to understand The impact of engineering solutions in a global, economic, environmental, and societal context
<i>I</i>	Recognition of the need for, and an ability to engage in life-long learning
<i>J</i>	Knowledge of contemporary issues
<i>K</i>	Ability to use the techniques, skills, and modern engineering tools necessary for electrical engineering practice

# What are Course learning outcomes?

Departmental or programmatic learning outcomes broadly describe the learning that will take place across the curriculum through **concise statements, made in specific and measurable terms**, of what students will **know and/or be able to do** at particular educational milestones (such as the completion of a course, certificate or degree).

# Programme Outcome Assessment Matrix

Outcome indicators & core courses	Outcome 1	Outcome 2
Project Report	1	2
Course 1	2	2
Course 2	3	2

1: slightly, 2: moderately, 3:substantively - base on a review of course materials (syllabus, learning outcomes, tests, other assessment.....)

Outcome 1: ability to .....

Outcome 2: ability to .....

# Course Assessment Matrix

Outcome-related learning objectives	Outcome 1	Outcome 2
<b>Explain</b>	<b>1</b>	<b>3</b>
<b>Perform calculation</b>	<b>2</b>	<b>2</b>
<b>Identify</b>	<b>2</b>	<b>2</b>
<b>Solve</b>	<b>2</b>	<b>3</b>

1: slightly, 2: moderately, 3:substantively

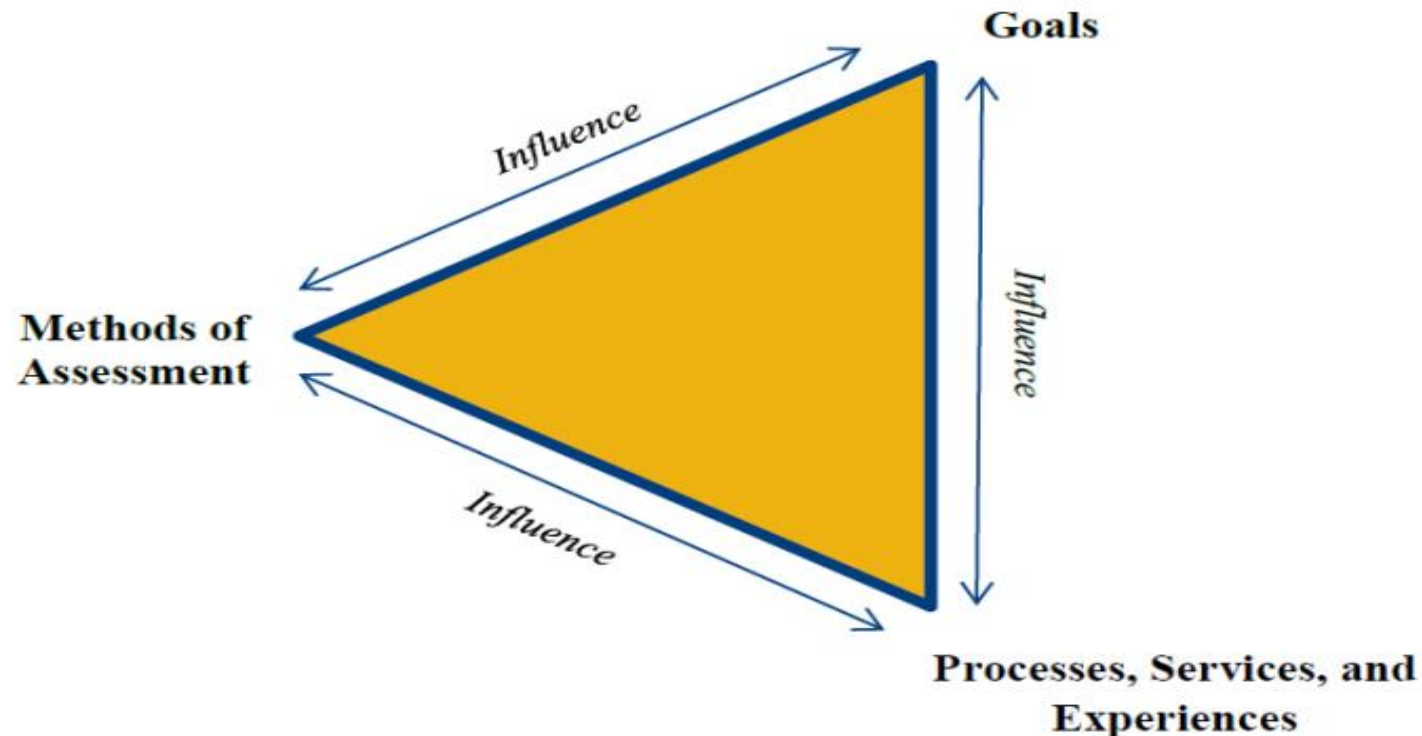
Outcome 1: ability to .....

Outcome 2: ability to .....

# What is a Programme Map?

A program map is a matrix that visually represents the alignment between program goals and their associated outcomes and the methods through which those outcomes are delivered.

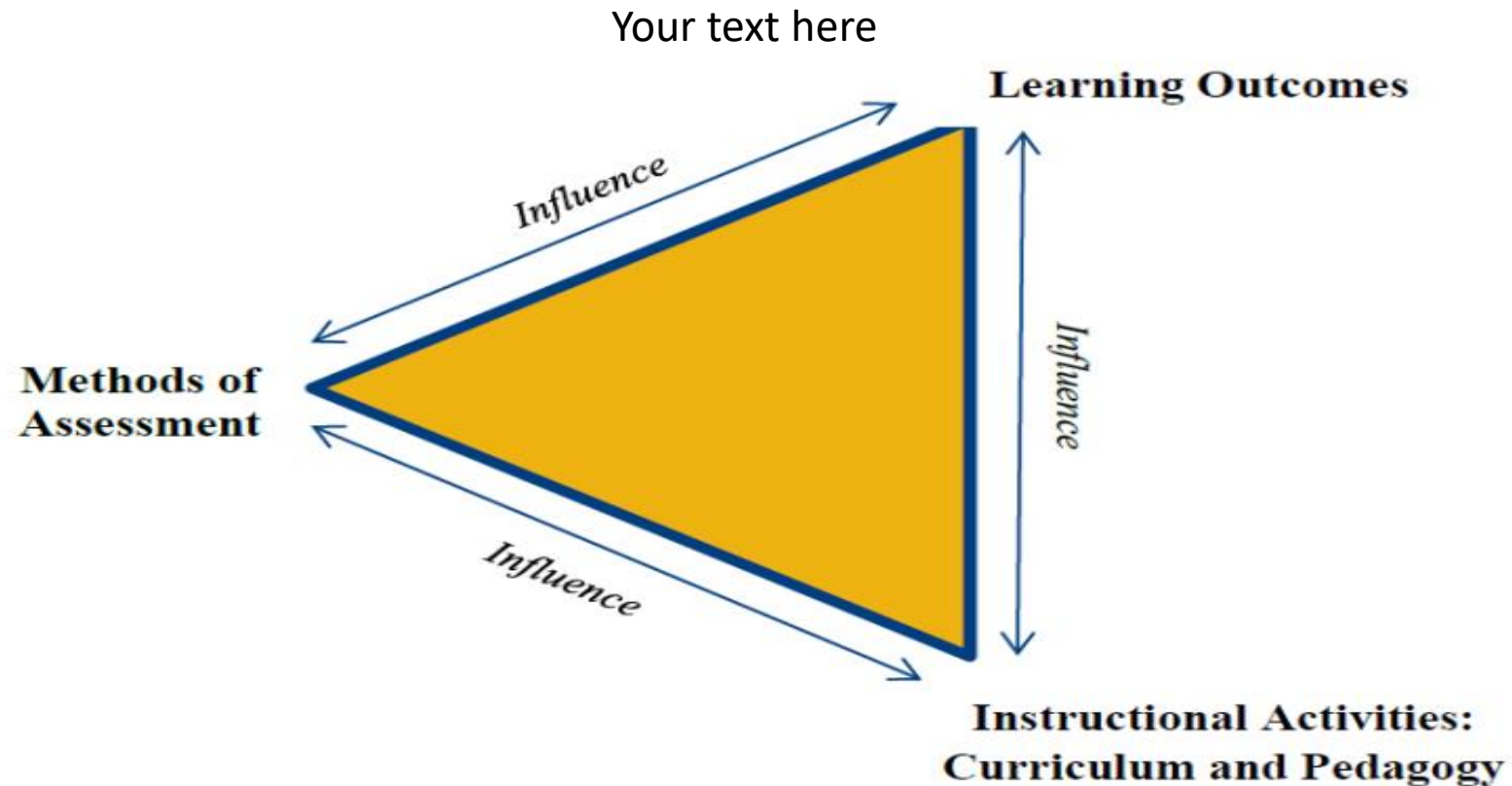
POs against PEOs plus the methods to be used for its achievements



# What is a Curriculum Map?

A curriculum map is a matrix that visually represents the alignment between Programme Outcomes and required courses/experiences.

POs against Courses



# Characteristics of Good Course Learning Outcomes

Learning outcomes assist the Programme to:

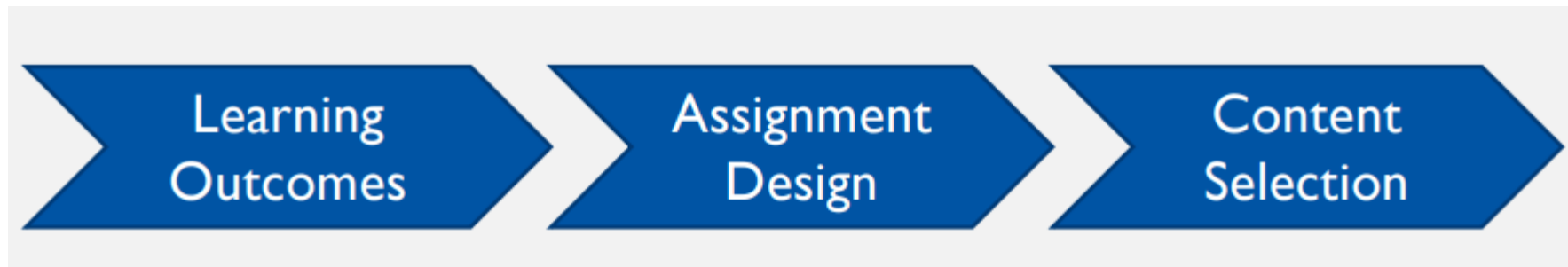
1. Think about their curriculums: by identifying areas within the programme where outcomes may overlap (or otherwise be redundant) or where gaps may exist.
2. Indicate what knowledge, skills and abilities students are expected to have mastered at the end of their course of study and allow them to communicate expectations to students.
3. Provide students with a way to articulate the knowledge and abilities that they have gained and to express what they know to others.
4. Assist staff in determining appropriate assessment strategies.
5. Inform potential employers of the abilities of a department's graduates.

# Steps in Writing Course Learning Outcomes

1. Reflect with other academic staff and other stakeholders on the question: **What it is that graduates should know or be able to do with a degree in your discipline?**
2. Refer to resources from your discipline, department, college, and the university about expectations of graduates. (Disciplinary associations' websites and publications, department and institutional learning goals, missions, and vision statements.
3. Draft questions in outcome form. In order to keep the outcomes student centered, begin each one with "Students will be able to..." and choose action verbs that can be observed and measured.
4. Share the draft outcomes with others to be certain that the most significant learning is captured in the outcomes and that the language is written in such a way that it is understandable to those who do not have a background in the field (advisors, potential students and their parents, employers).

# HOW DO WE USE CLO'S?

1. CLO's can be used to design learning experiences that are intentional, clear, and center on what students can do.
2. Backward design is an approach to teaching and curriculum design. It is most often attributed to the 1998 book, *Understanding By Design* (Wiggins & McTighe).
3. Most instructional design starts with the content, i.e. what will be taught. Backward design instead begins with learning goals, then moves backward to assessment and content selection.



# Why Write Course Learning Outcomes?

Outcomes, when presented clearly and aligned to good curriculum and teaching practices, help promote “deep learning” for students (see Driscoll & Wood).

1. Clarity about what and how students are learning helps fill equity gaps, particularly for first-time students.
2. For example: one of the SLO’s for English 001 is: “Students will write essays that develop logically and use cogent and sufficient evidence to support a complex argument.”
3. In class, students might complete a series of shorter, “formative” assignments, such as locating and summarizing a source, or creating an outline, that explicitly lead toward this goal.
4. In a final, “summative” essay or portfolio of writing, student work would be assessed based on how well the course outcome is met.

# Why Write Course Learning Outcomes?...

5. The goal is that while completing the formative tasks, students will understand the purpose of their learning—they can build and apply the knowledge and skills gained throughout the semester to a larger task.
6. This understanding promotes “deep learning”—the ability to make connections between tasks, reflect on progress, and encourage student interest and intrinsic motivations

# Why Write Course Learning Outcomes?

Learning outcomes help instructors...

1. describe to students what is expected of them
2. plan appropriate teaching strategies, materials and assessments
3. learn from and make changes to curriculum to improve student learning
4. assess how the outcomes of a single course align with larger outcomes for an entire programme

# Why Write Course Learning Outcomes?...

Learning outcomes help students...

1. anticipate what they will gain from an educational experience
2. track their progress and know where they stand
3. know in advance how they'll be assessed

# Examples of Common Course Learning Outcome Problems and Solutions

## **Not Student-Centered**

Different theories of personality development will be explored through lectures, readings, and assignments.

## **Not Measurable**

Students will understand symbolism.

## **Not Clear**

Students will be able to analyze American history.

## **Student-Centered**

Students will name each theory of personality development and describe the key characteristics that distinguish each theory.

## **Measurable**

Students will be able to identify examples of symbolism in short stories and incorporate symbolism in their own writing.

## **Clear**

Students will be able to analyze how American foreign policy history relates to current trends in American foreign policy.

## **Not Concise**

Students will analyze American foreign policy, from 18th-century diplomatic relations with Europe to the Monroe Doctrine, considering the ways in which shifts from expansionism and Manifest Destiny to isolationism and protectionism impacted relations with neighboring nations and Native Americans.

## **Task-Based (Inflexible)**

Students will be able to demonstrate on a mannequin the four steps to administer CPR.

## **Concise**

Students will be able to identify how changes in American foreign policy during the 18th and 19th centuries impacted relations with neighboring nations and Native Americans

## **Outcome-Based (Flexible)**

Students will be able to demonstrate the four steps used to administer CPR.

## Activity: Outcome Mapping

1. Select a course you are teaching this semester
2. Identify and understand POs adopted by your institution for the Programme. Then after, assign relevant POs that can be achieved through the Course selected.
3. Develop several CLOs from the course synopsis .
4. Identify which of the POs are strongly related or correlated to the CLOs you developed. Propose a matrix of CLOs with different levels of correlation to the POs adopted such as 0,1,2 and 3 for No, Slightly (Low) Moderately (Medium) and Substantially (High) respectively.
5. Should the CLO be Introduced, Reinforced, Emphasized, or Achieved in this course?

## REFERENCES & FURTHER READING

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4. CCCCO Guided Pathways Resource Library: <http://cccgp.cccco.edu/library-of-resources>
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