COMPLEX ENGINEERING PROBLEM (WP) and COMPLEX ENGINEERING ACTIVITIES (EA)

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OUTLINE

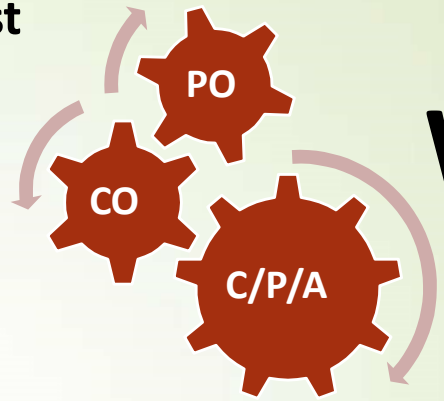
1. WK-WA-WP-EA Mapping
2. WP Characteristics and Requirements
3. EA Characteristics and Requirements

Refresher

CONSTRUCTIVE ALIGNMENT

Intended outcomes must clearly be indicated

WHAT



WP&EA

ELEMENTS OF COURSE DESIGN

learning outcomes

CLOSE LOOP

STUDENT

SCL	TCL
PBL	Lecture
POPBL	E-Learning
CBL	
Blended	
Laboratory	

instruction ⟷ **assessment**

HOW TO HELP

HOW TO KNOW

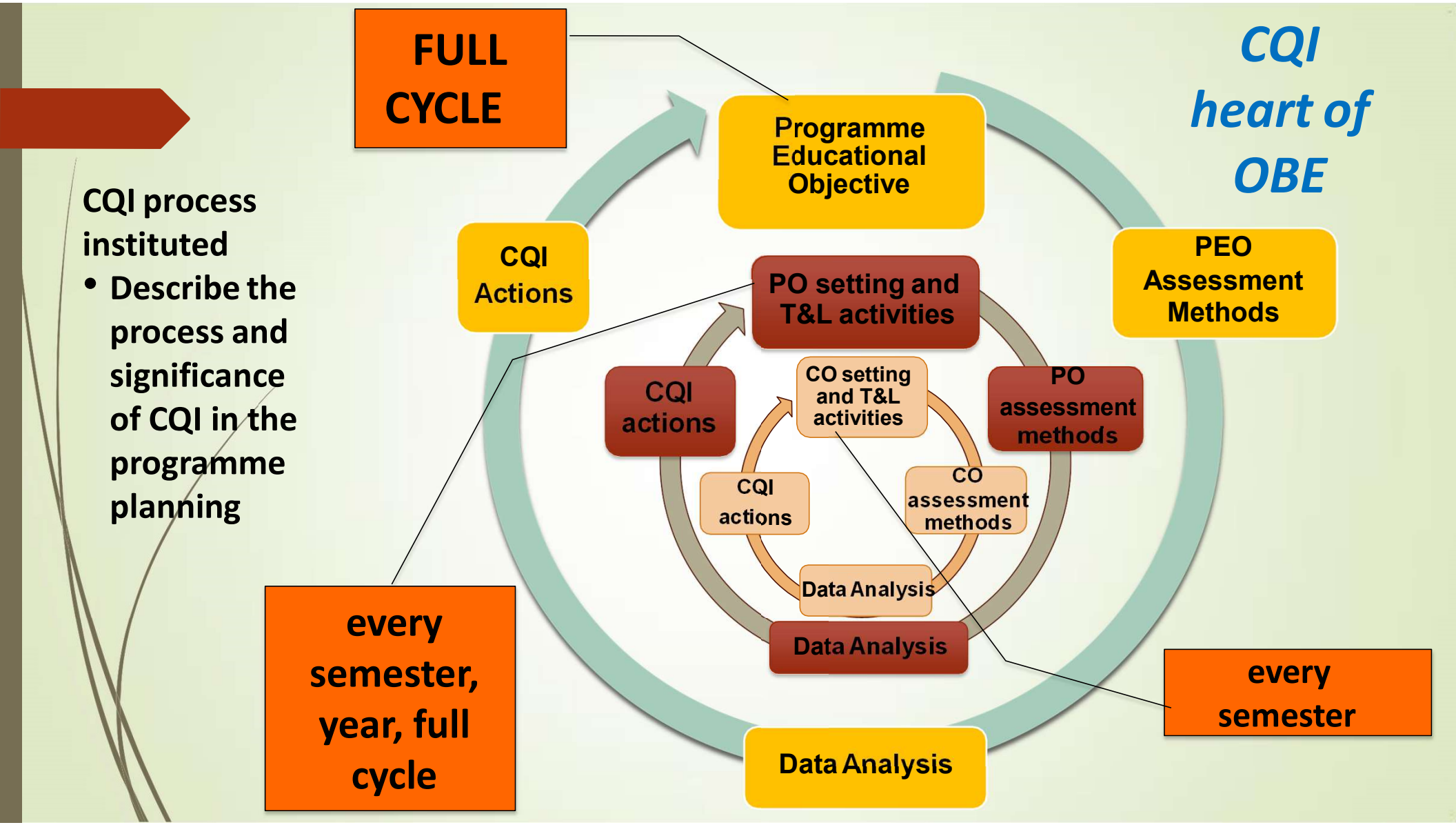
- Formative/ Summative
- Direct/ Indirect
- Course/ Programme Level

Activity will match outcomes

OBE requires T&L activities to be CONSTRUCTIVELY ALIGNED to intended learning outcomes

CQI process instituted

- Describe the process and significance of CQI in the programme planning



PO ASSESSMENT MODELS

1. • **Accumulated model** – **ALL** courses contributing to the PO measurements

2. • **Dominating model** – **SELECTED** courses contributing to the PO measurements, normally accounted in several CORE courses.

3. • **Culminating model** – **SELECTED FEW** usually between 3-5 courses contributing to the PO measurements, normally conducted during the final year of study.

INTERNATIONAL ENGINEERING ALLIANCE

Defining standards of education and professional competence.
(https://www.ieagreements.org)
Version 1: June 2005
Version 2: June 2009
VERSION 3: JUNE 2013

International agreements GOVERN the recognition of engineering educational qualifications and professional competence, thus establishing and enforcing internationally benchmarked standards.

EDUCATION ACCORDS

- WA (20 MEMBER COUNTRIES) 1989
- SA (11 MEMBER COUNTRIES) 2001
- DA (9 MEMBER COUNTRIES) 2002

AGREEMENTS

- APEC
- IPEA
- IETA
- AIET

WA

Signed in 1989, the **Washington Accord**, is a multi-lateral agreement between bodies responsible for accreditation or recognition of tertiary-level engineering qualifications within their jurisdictions who have chosen to work collectively to **assist the mobility of professional engineers.**

- The Washington Accord is specifically focused on *academic programmes* which deal with the practice of **engineering at the professional level.**

SA

- The **Sydney Accord** is specifically focused on academic programmes dealing with **engineering technology.**
- The Accord acknowledges that accreditation of these academic programmes is a key foundation for the practice of engineering technology in each of the countries or territories covered by the Accord.
- It recognises the **importance of the roles engineering technologists as part of a wider engineering team.**

DA

- The **Dublin Accord** is specifically focused on the mutual recognition of academic programmes/ qualifications that underpin the **educational base for Engineering Technicians.**
- The Accord acknowledges that the educational base is a key foundation for practice as an engineering technician, in each of the countries or territories covered by the Accord.
- It recognises the **importance of the roles engineering technicians play as part of a wider engineering team.**

WA Member Countries

1. Australia - (EA) (1989)
2. Canada – (EC) (1989)
3. China - (CAST) (2016)
4. Chinese Taipei - (IEET) (2007)
5. Hong Kong China - (HKIE) (1995)
6. India - (NBA) (2014)
7. Ireland - (EI) (1989)
8. Japan - (JABEE) (2005)
9. Korea - (ABEEK) (2007)
10. Malaysia - (BEM) (2009)
11. New Zealand - (IPENZ) (1989)
12. Russia - (AEER) (2012)
13. Singapore - (IES) (2006)
14. South Africa - (ECSA) (1999)
15. Sri Lanka - (IESL) (2014)
16. Turkey - (MÜDEK) (2011)
17. United States - (ABET) (1989)
18. United Kingdom - (ECUK) (1989)
19. Pakistan - (PEC) (2017)
20. Peru – (ICACIT) (2018)

PROVISIONAL MEMBERS

1. Bangladesh - (IEB)
2. Costa Rica - (CFIA)
3. Mexico - (CACEI)
4. Philippines - (PTC)
5. Chile – (ACREDITA CI)
6. ***Thailand - (TABEE)***
7. ***Indonesia - (IABEE)***
8. ***Myanmar - (MEC)***

SA Member Countries

1. Australia - (EA) (2001)
2. Canada - (CCTT) (2001)
3. Chinese Taipei - (IEET) (2014)
4. Hong Kong China - (HKIE) (2001)
5. Ireland - (EI) (2001)
6. Korea - (ABEEK) (2013)
7. New Zealand - (IPENZ) (2001)
8. South Africa - (ECSA) (2001)
9. United Kingdom - (ECUK) (2001)
10. United States - (ABET) (2009)
11. **MALAYSIA – (BEM) (2018)**

PROVISIONAL MEMBERS

1. Peru - (ICACIT)
2. Sri Lanka – (IESL)

DA Member Countries

1. Australia - (EA) (2013)
2. Canada - (CCTT) (2002)
3. Ireland - (EI) (2002)
4. New Zealand - (IPENZ) (2013)
5. Korea - (ABEEK) (2013)
6. South Africa - (ECSA) (2002)
7. United Kingdom - (ECUK) (2002)
8. United States - (ABET) (2013)
9. **MALAYSIA – (BEM) (2018)**

PROVISIONAL MEMBERS

NONE to date

WA

PROFESSIONAL ENGINEERING GRADUATES
are expected to work with Complex Engineering Problems

Complex Engineering Problems (Engineer)
Requires in-depth knowledge that allows a fundamentals-based first principles analytical approach

Complex Engineering Activities or Projects

SA

TECHNOLOGIST GRADUATES
to work with Broadly Defined Engineering Problems

Broadly Defined Problems (Technologist)
Requires knowledge of principles and applied procedures or methodologies

Broadly Defined Engineering Activities or Projects

DA

TECHNICIAN GRADUATES
to work with Well-Defined Engineering Problems

Well-defined Problems (Technician)
Can be solved using limited theoretical knowledge, but normally requires extensive practical knowledge

Well-defined Engineering Activities or Projects

TERMINOLOGIES

WP	• Complex Problem Solving
EA	• Complex Engineering Activities
WA=PO	• Graduate Attributes **(PO1-PO12)**
WK	• Knowledge Profile

WA Graduate Attributes	
WA1/PO1 - Engineering Knowledge	Apply mathematics, natural science, engineering fundamentals and engineering specialization to the solution of **complex engineering *problems*** **(WK1, WK2, WK3, WK4)**
WA2/PO2 - Problem Analysis	Identify, formulate, research literature & analyse **complex engineering *problems*** using first principles of mathematics, natural sciences and engineering sciences **(WK1, WK2, WK3, WK4)**
WA3/PO3 - Design/ Development of Solutions	Design solutions for **complex engineering *problems*** and design systems, components or processes with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. **(WK5)**
WA4/PO4 - Investigation	Conduct investigations of **complex *problems*** using research-based knowledge and research methods **(WK8)**
WA5/PO5 - Modern Tool Usage	Create, select and apply modern engineering and IT tools including prediction and modelling to **complex engineering *problems*** **(WK6)**
WA6/PO6 - The Engineer and Society	Apply reasoning to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to **complex engineering *problems*** **(WK7)**

WA Graduate Attributes	
WA7/PO7 - Environment and Sustainability	Understand and evaluate the sustainability and impact of professional engineering work in the solution of **complex engineering *problems*.** **(WK7)**
WA8/PO8 - Ethics	Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. **(WK7)**
WA9/PO9 - Individual and Team Work	Function effectively as an individual, member or leader in diverse teams and in multi-disciplinary settings
WA10/PO10 - Communication	Communicate effectively on **complex engineering *activities*** with the engineering community and with society able to comprehend, write, present, give and receive instructions
WA11/PO11 - Project Management and Finance	Demonstrate knowledge and understanding of engineering management principles and economic decision-making, apply to own work, as a member and leader in a team, manage projects and in multidisciplinary environments
WA12/PO12 - Lifelong learning	Recognize the need, prepare and engage in independent and life-long learning

	IEA KNOWLEDGE PROFILE	
WK1	**Natural sciences**	A systematic, theory-based understanding of the natural sciences applicable to the discipline.
WK2	**Mathematics**	Conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to thediscipline.
WK3	**Engineering fundamentals**	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	**Specialist Knowledge**	Engineering specialist knowledge 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.
WK5	**Engineering Design**	Knowledge that supports engineering design in a practice area.
WK6	**Engineering Practice**	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	**Comprehension**	Comprehension 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.
WK8	**Research literature**	Engagement with selected knowledge in the research literature of the discipline.

	PROFESSIONAL ENGINEERING GRADUATES - Complex Engineering Problems		TECHNOLOGIST GRADUATES - Broadly Defined Engineering Problems		TECHNICIAN GRADUATES – Well - Defined Engineering Problems	
GRADUATE ATTRIBUTES (IEA) – PO	**WK**	**WP/EA**	**SK**	**SP/TA**	**DK**	**DP/NA**
1. Engineering Knowledge	WK1-WK4	WP	SK1-SK4	SP	DK1-DK4	DP
2. Problem Analysis	WK1-WK4	WP	SK1-SK4	SP	DK1-DK4	DP
3. Design/Development of Solutions	WK5	WP	SK5	SP	DK5	DP
4. Investigation	WK8	WP	SK8	SP	-	DP
5. Modern Tool Usage	WK6	WP	SK6	SP	DK6	DP
6. The Engineer and Society	WK7	WP	SK7	SP	DK7	DP
7. Environment and Sustainability	WK7	WP	SK7	SP	DK7	DP
8. Ethics	WK7		SK7		DK7	
9. Individual and Team work						
10. Communication		EA		TA		NA
11. Project Management and Finance						
12. Life Long Learning						

Assessments Provide Adequate Feedback To The Programme To Identify Strengths And Weaknesses For CQI

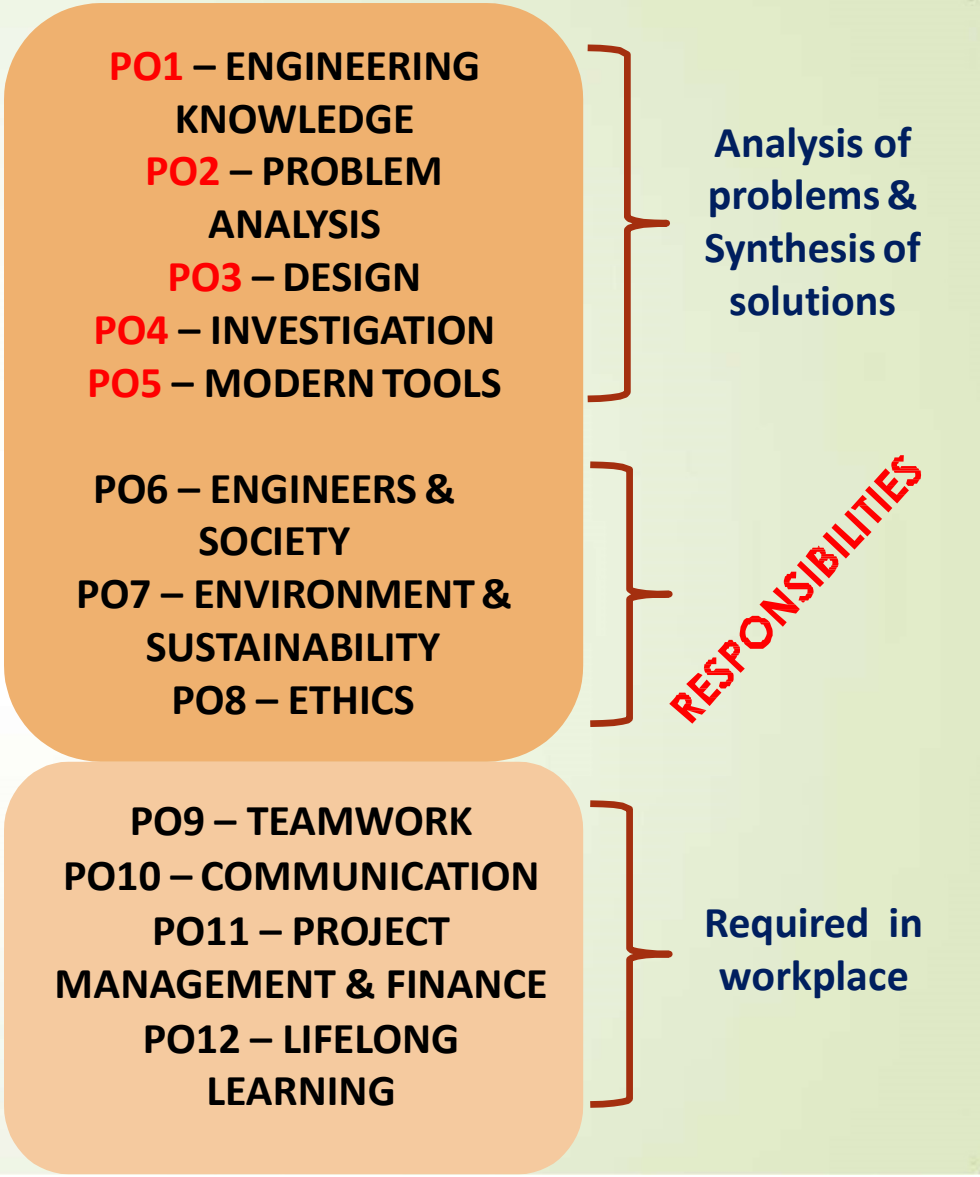
KEYWORD	Complex Engineering Problems have characteristics WP1 and some or all of WP2 to WP7
WP1 **Depth of knowledge required**	Cannot be resolved without **in-depth engineering knowledge** at the level of one or more of **WK3, WK4, WK5, WK6 or WK8** which allows a fundamentals-based, first principles analytical approach.
WP2 **Range of conflicting requirements**	Involve **wide-ranging or conflicting** technical, engineering and other issues.
WP3 **Depth of analysis required**	Have **no obvious solution** and require abstract thinking, originality in analysis to formulate suitable models.
WP4 **Familiarity of issues**	Involve **infrequently** encountered issues
WP5 **Extent of applicable codes**	Are **outside problems** encompassed by **standards and codes of practice** for professional engineering
WP6 **Extent of stakeholder involvement & conflicting requirements**	Involve **diverse** groups of stakeholders with **widely varying needs**
WP7 **Interdependence**	**High level problems** including many component **parts or sub-problems**

	PROFESSIONAL ENGINEERING GRADUATES - Complex Engineering Problems		TECHNOLOGIST GRADUATES - Broadly Defined Engineering Problems		TECHNICIAN GRADUATES – Well - Defined Engineering Problems	
GRADUATE ATTRIBUTES (IEA) – PO	**WK**	**WP/EA**	**SK**	**SP/TA**	**DK**	**DP/NA**
1. Engineering Knowledge	*WK1-WK4*	WP	SK1-SK4	SP	DK1-DK4	DP
2. Problem Analysis	*WK1-WK4*	WP	SK1-SK4	SP	DK1-DK4	DP
3. Design/Development of Solutions	*WK5*	WP	SK5	SP	DK5	DP
4. Investigation	*WK8*	WP	SK8	SP	-	DP
5. Modern Tool Usage	*WK6*	WP	SK6	SP	DK6	DP
6. The Engineer and Society	WK7	WP	SK7	SP	DK7	DP
7. Environment and Sustainability	WK7	WP	SK7	SP	DK7	DP
8. Ethics	WK7		SK7		DK7	
9. Individual and Team work						
10. Communication		EA		TA		NA
11. Project Management and Finance						
12. Life Long Learning						

Assessments Provide Adequate Feedback To The Programme To Identify Strengths And Weaknesses For CQI

WK & PO RELATIONSHIP

WK1	Theory-based natural sciences	PO1 – ENGINEERING KNOWLEDGE PO2 – PROBLEM ANALYSIS
WK2	Conceptually-based mathematics	
WK3	Theory-based engineering fundamentals	
WK4	Forefront specialist knowledge for practice	
WK5	Engineering design	PO3 – DESIGN
WK6	Engineering practice (technology)	PO5 – MODERN TOOLS
WK7	Comprehension of engineering in society	PO6 – ENGINEERS & SOCIETY PO7 – ENVIRONMENT & SUSTAINABILITY PO8 – ETHICS
WK8	Research literature	PO4 – INVESTIGATION



COMPLEX ENGINEERING PROBLEMS - (WP1 & some OR ALL of WP2 -WP7)

WP1

In–Depth Knowledge = knowledge gained from courses/ learning activities beyond the introductory instructional level

1st Principles = the fundamental concepts/ assumptions on which a theory, system, or method is based.

In engineering, 1st Principles start directly at the level of established laws of chemistry, physics and mathematics.

The required theoretical knowledge to solve problem/develop the design.

For example,

- ***Apply detailed theoretical knowledge working from 1st Principles to establish a workable mathematical or theoretical model***
- ***Apply some standard formulae or theoretical models mixed by exposure to similar problems***

WP2	**Range of conflicting requirements**	Involve **wide-ranging** or **conflicting** technical, engineering and other issues.

What constraints are placed to resolve the problem?

What conflicting demands in the developing a design?

How the constraints were identified

- **they may have been part of the brief,**
- **they may have only become apparent once they started addressing the problem, or**
- **the brief may have implied or only referenced to them loosely.**

WP3	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.

What are guidance/ constraints given to develop the solution/ design?

Multiple solutions

Approach to the development of solution/design

- How was the problem defined?
- Students may have been given clear boundaries and specific details of what they had to do, or they may have had to define some or all of the boundaries to the problem themselves and work with limited information to decide how the work should be carried out
- The problem may have been the one that they regularly encountered but with slight case-specific variations.

WP4	**Familiarity of issues**	**Involve infrequently encountered issues**

To what extent is this problem routinely encountered and resolved using well-understood practices?

The problem is a:

- ***New problem*** **not previously or only rarely encountered.**
- ***Familiar problem*** **with either:**
  - **Clearly defined methods and/or practices used to resolve.**
  - **Some (or many) unique issues that made resolution difficulty level increases.**

WP5	**Extent of applicable codes**	**Are outside problems encompassed by standards and codes of practice for professional engineering**

How do existing standards, codes dictate the solution?

How to analyse/ investigate or develop a solution/ design by either:

- **Applying engineering skill to address some parts of the problem that were not clearly prescribed by standards, codes or practices.**
- **Having to develop own criteria (in a manner consistent with good engineering practice) because the problem was so ill-defined that it did not fall within any specific standards, codes or codified engineering practices.**

WP6	**Extent of stakeholder involvement and level of conflicting requirements**	**Involve diverse groups of stakeholders with widely varying needs.**

How do stakeholder interests and requirements impact on the problem?

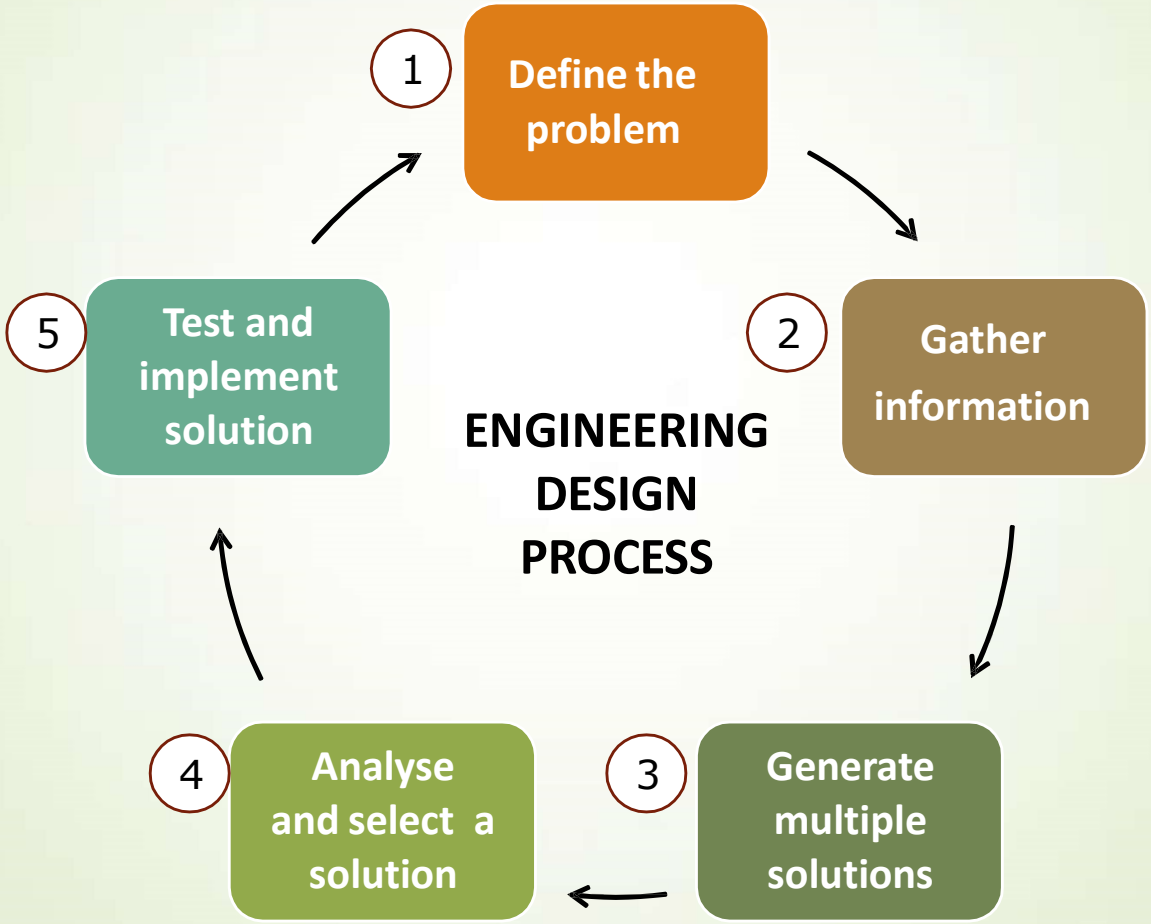
Are there conflicting requirements? If so, how did you interact with affected stakeholders to resolve the conflicts?

- **Who are your stakeholders?**
- **What are their interests or requirements ?**
- **The extent these interests or requirements conflicted and/or placed constraints on the problem**
- **How do you manage your stakeholders to resolve conflicts, meet their requirements or reach satisfactory compromises ?**

WP7	**Interdependence**	**Are high level problems including many component parts or sub-problems.**

The problem is able to be broken down into smaller components or sub-problems, not physically but mathematically

TYPICAL DESIGN PROCESS



STEP 1 - DEFINE THE PROBLEM

PROBLEM DEFINITION STATEMENT: A BETTER MOUSETRAP

Certain rodents such as the common mouse are carriers and transmitters of an often fatal virus, the hantavirus. Conventional mousetraps expose people to this virus as they handle the trap and dispose of the mouse. Design a mousetrap that allows a person to trap and dispose of a mouse without being exposed to any bacterial or viral agents being carried on the mouse.

Criteria for Success of a Better Mousetrap

WP2	Range of conflicting requirements

- The design must be low cost.
- The design should be safe, particularly with small children.
- The design should not be detrimental to the environment.
- The design should be aesthetically pleasing.
- The design should be simple to operate, with minimum human effort.
- The design must be disposable. (You don't reuse the trap.)
- The design should not cause undue pain and suffering for the mouse.

STEP 2 – GATHER INFORMATION

(Search for Information & Record the Results)

WP2	Range of conflicting requirements
WP4	Familiarity of issues
WP6	Extent of stakeholder involvement and level of conflicting requirements

- What are the existing solutions to the problem?
- What is wrong with the way the problem is currently being solved?
- What is right with the way the problem is currently being solved?
- What companies manufacture the existing solution to the problem?
- What are the economic factors governing the solution?
- How much will people pay for a solution to the problem?
- What other factors are important to the problem solution (such assafety, aesthetics, environment issues, and colour)?

Sources of information: *e-book, journal, technical handbook*
Engineer's logbook: *Record the results*

STEP 3 - GENERATE MULTIPLE SOLUTIONS

WP3 | Depth of analysis

- The importance of teamwork – creative solutions to technical problems are not solved by individuals but by a team of people from different technical background bringing different perspective to the problem
- Strategies for generating creative solutions – brainstorming is a technique of generating many ideas & sketch-storming is the visual creation and recording of ideas

STEP 4 – ANALYSE AND SELECT A SOLUTION

- Analysis of design solutions – design problem is unique & requires different types of analysis
  - Functional analysis
  - Ergonomics
  - Product safety and liability
  - Economic and market analysis
  - Strength, mechanical, thermal analysis
- Decision process

WP1	Depth of knowledge
WP3	Depth of analysis
WP5	Extent of applicable codes

STEP 5 - TEST AND IMPLEMENT SOLUTION

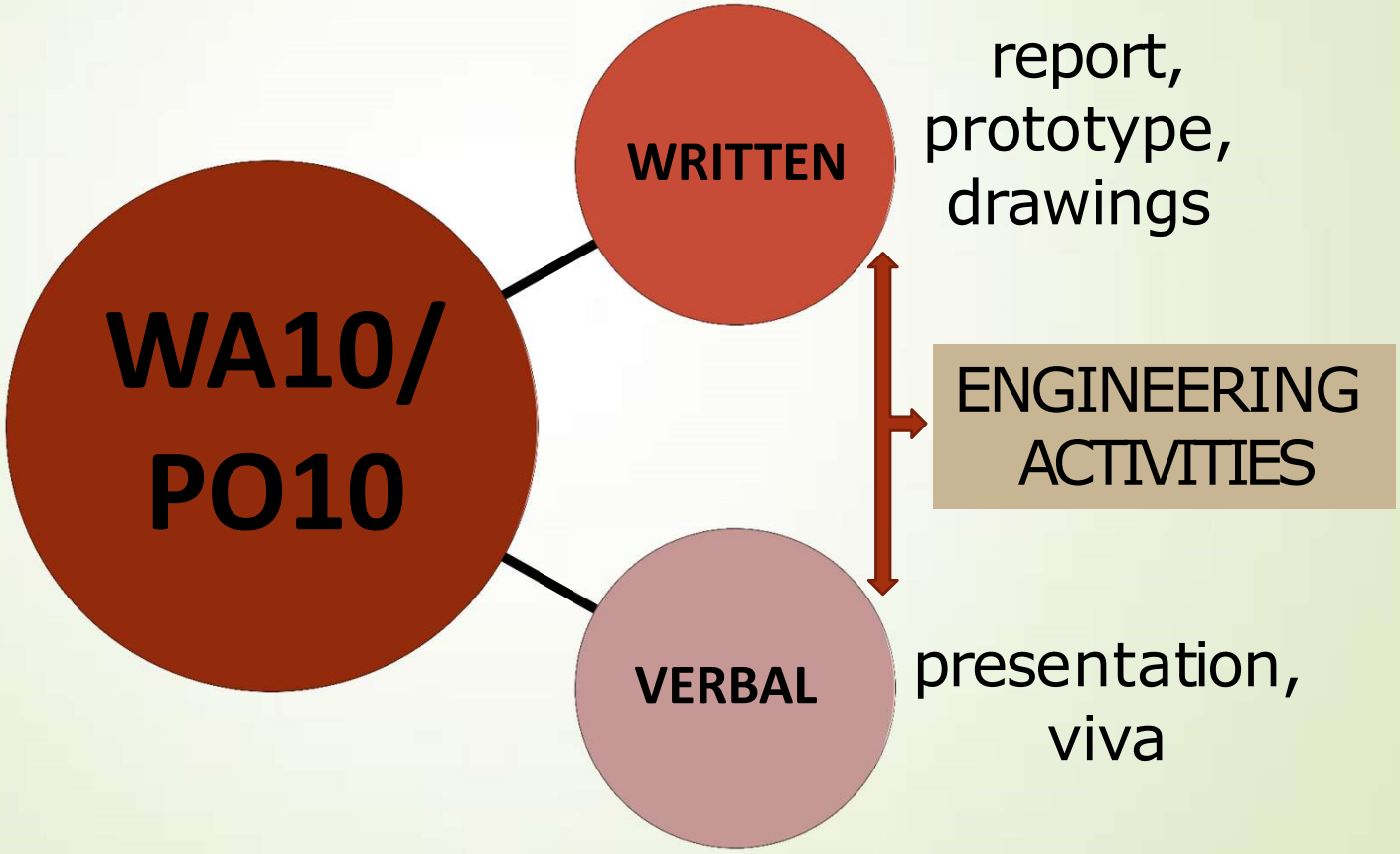
- Prototyping
- Documenting the solution – engineering drawing, written communication, oral communication, scheduling and planning

WP1	Depth of knowledge
WP5	Extent of applicable codes

Complex Engineering Activities

WA10/PO10: **COMMUNICATION** ~COMPLEX ENGINEERING ACTIVITIES (EA)

COMMUNICATE effectively on **complex engineering activities** with the engineering community and with society, able to comprehend, write, present, give and receive instructions



COMPLEX ENGINEERING ACTIVITIES –
(some OR ALL of EA1-EA5)

CAN BE REASONABLY ENCOUNTERED DURING IDP & INDUSTRIAL TRAINING

KEYWORD	Complex Engineering Activities mean engineering activities or projects that have some or all the following characteristics:
EA1 Range of resources	Involve the use of **diverse resources** (and for this purpose resources includes people, money, equipment, materials, information and technologies)
EA2 Level of interactions	Require resolution of **significant problems** arising from **interactions between wide-ranging or conflicting technical, engineering or other issues**
EA3 Innovation	Involve **creative use** of engineering principles and research-based knowledge in novel ways
EA4 Consequences to society and the environment	Have **significant consequences** in a range of contexts, characterized by difficulty of prediction and mitigation
EA5 Familiarity of issues	Can extend **beyond** previous experiences by applying principles-based approaches

EA1	**Range of resources**	**Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials, information and technologies).**

What resources were available to help you carry out this engineering activity?

Negotiate adequate resources eg personnel, funding, equipment, authorisations to undertake work materials

Develop plans (including budgets) to schedule availability of resources for allocation when required to meet project timelines and financial commitments.

Report work progress against schedule – work-flow plans, budgets, overall project performance objectives and provide projections on work completion to target times and budget

EA2	**Level of interactions**	**Require resolution of significant problems arising from interactions between wide ranging or conflicting technical, engineering or other issues.**

What are the engineering issues or other issues that could impact on engineering matters related to the project - the expected outset of the project ?

What unforeseen engineering issues arose during the execution of the project ?

Prior to commencing the work to ensure all the engineering issues are resolved or scheduled to be resolved to meet project plan targets, i.e., identify the potential risks with the respective proposed solution.

EA3	**Innovation**	**Involve creative use of engineering principles and research-based knowledge in novel ways**

What new techniques, materials or processes can be utilised in the project, feasibility study (technical & economy), literature review ?

How do the proposed approach improve the efficiency, effectiveness or quality of work? Such as *ROI, quality, economy and sustainability.*

What are the creative solutions and out of the box thought processes undertaken/happened to promote innovation ?

EA4	**Consequences to society and the environment**	**Have significant consequences in a range of contexts, characterised by difficulty of prediction and mitigation.**

What are the impacts of the engineering solution on the society and environment?

Who is affected and how?

EA5	**Familiarity**	**Can extend beyond previous experiences by applying principles-based approaches.**

To what extent is the previous experiences routinely encountered and resolved using well-understood practices?

The experience is a:

a. **New experience which is not previously or only rarely encountered.**

b. **Familiar experience with either:**

- **Clearly defined approaches and/or practices used to resolve.**
- **Some (or many) unique issues that made communication difficulty level increases.**

COURSES FOR IMPLEMENTING COMPLEX ENGINEERING PROBLEMS

- **Industry-based Integrated Design Project**
  - Employed Problem-Based Learning teaching method
  - Provides students opportunity to apply their skills and knowledge toward developing a robust understanding of what it means to be an engineer
  - Supports students to make **transition from classroom-based activities to professional communities of practices**
  - Working with a supervisor from the industry in a type of collaboration, students are challenged with a real-world problem.
- **Final Year Project**
  - Commonly known as **research project**
  - Best means of introducing an **investigative research-oriented approach** to engineering studies and sourcing of knowledge externally from the real-world
  - Involves **review of open research literature** which challenges students to interpret new information, perform critical analysis, form personal opinions and judgements, and learn independently
  - Open research literature is one of the assessments that **employs constructivist technique**.

COURSES FOR IMPLEMENTING COMPLEX ENGINEERING PROBLEMS

- **Industry Training or Work-based Learning**
  - Provides opportunities for students to engage in **experiential education, integrating theory with work experience**
  - Provides students with knowledge base and skills to help them **translate isolated and abstract concepts into practical applications** of that knowledge.
- **Laboratory experiences**
  - Important elements in engineering education, **bridging the gaps between engineering theories and real practices through cultivation of hands-on skills**
  - **Open-ended approach** - the problem may have multiple solutions and there is no obvious solution. Being a subset of problem-based learning, open-ended laboratory focuses on student's ability to design experiments, identify the variables or results or information to be collected and identify the appropriate instruments for the assigned problem. This approach suits the need to produce engineering graduates that are self-directed, reflective, demonstrate ability to integrate knowledge, think critically, practice life-long learning and work collaborative with others.

USE OF FINAL EXAMINATION FOR COMPLEX PROBLEM SOLVING

- **Many believe that examination is not suitable to assess complex engineering problem solving skills and it must involve activities, especially integrated activities and discussions, such as case study (Phang *et al*., 2018).**

- **Example of final examination question (Phang *et al*., 2018):**

Sungai Melana is a small river flowing through several residential areas in Skudai, Johor Bahru. You are a consultant appointed to propose a river restoration action plan for a part of Sungai Melana, beginning from the upstream at Taman Teratai until the midstream at Taman Universiti.

Your proposal should include action plans to accomplish the following objectives:

1. *Improving the water quality of Sungai Melan to Class II and III*
2. *Prevention of direct solid waste discharge into the river system*
3. *Creating suitable habitats for the propagation aquatic life*
4. *Adding property and aesthetic value to residents living along the river*

Your answers should be written to address each of these items separately.

Sharing Further Info

CO-PO-WK-WP-EA Matrix

Electrical Design Project

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Thank You