Addressing Complex Engineering Problems and Complex Engineering Activities

International Symposium on
Quality Assurance in Engineering Education Through Accreditation
26-27 August 20120
BAETE, Bangladesh

1.30 – 2.30 pm (Bangladesh Time)
3.30 – 4.30 pm (Malaysia Time)

Megat Johari Megat Mohd Noor

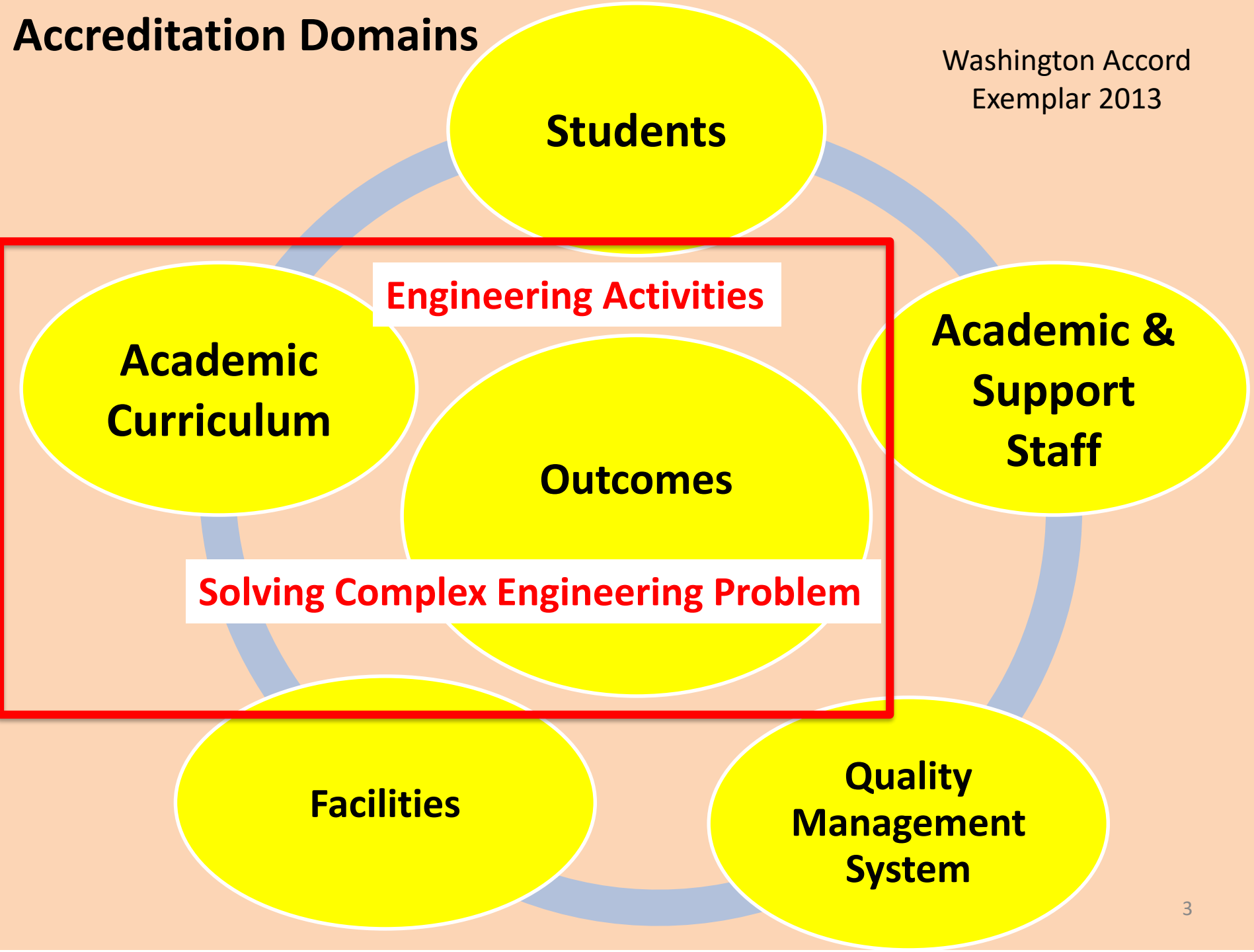
- *Board Member, Board of Engineers Malaysia (BEM)*
- *President, Malaysian Society for Engineering & Technology (MySET)*
- *Vice President, Federation of Engineering Institutions of Islamic Countries (FEIIC)*
- *Former Professor, Malaysia Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia (UTM), Kuala Lumpur*

Outlines

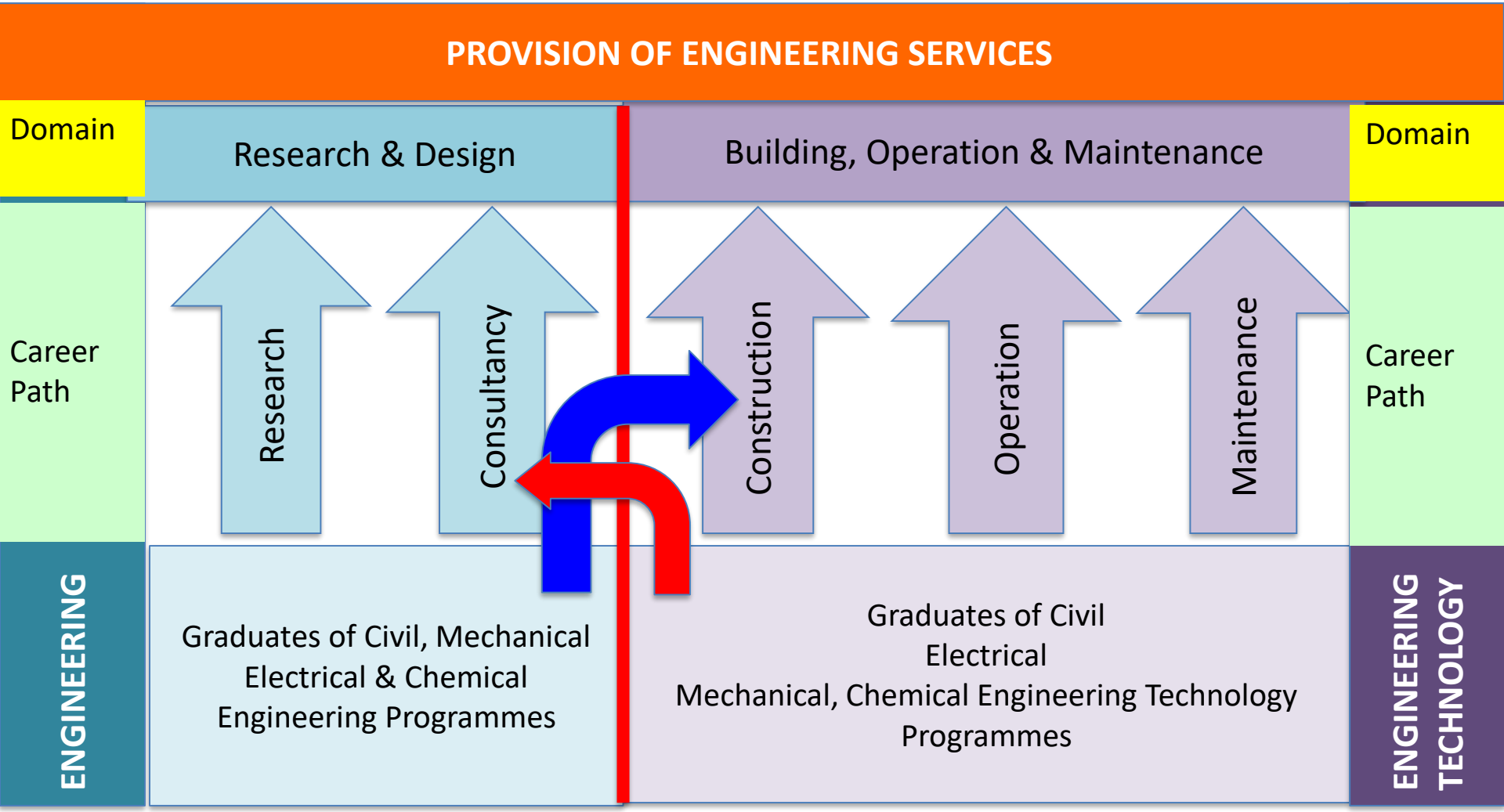
- Introduction
- Graduate Attributes
- Knowledge Profiles
- Complex Engineering Problem
- Engineering Activities
- Integration View
- Conclusion

Accreditation Domains

Washington Accord
Exemplar 2013



Career Paths

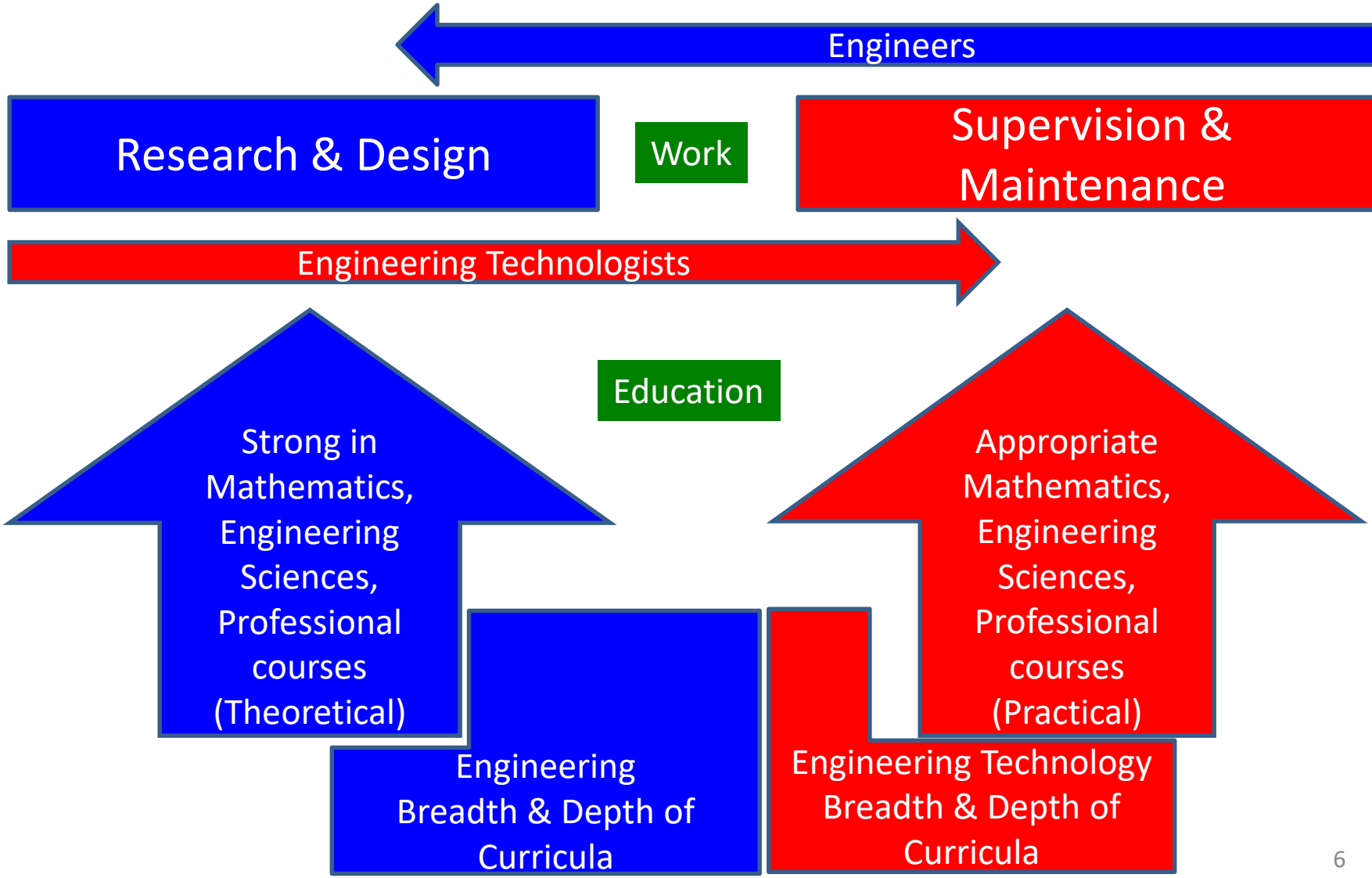


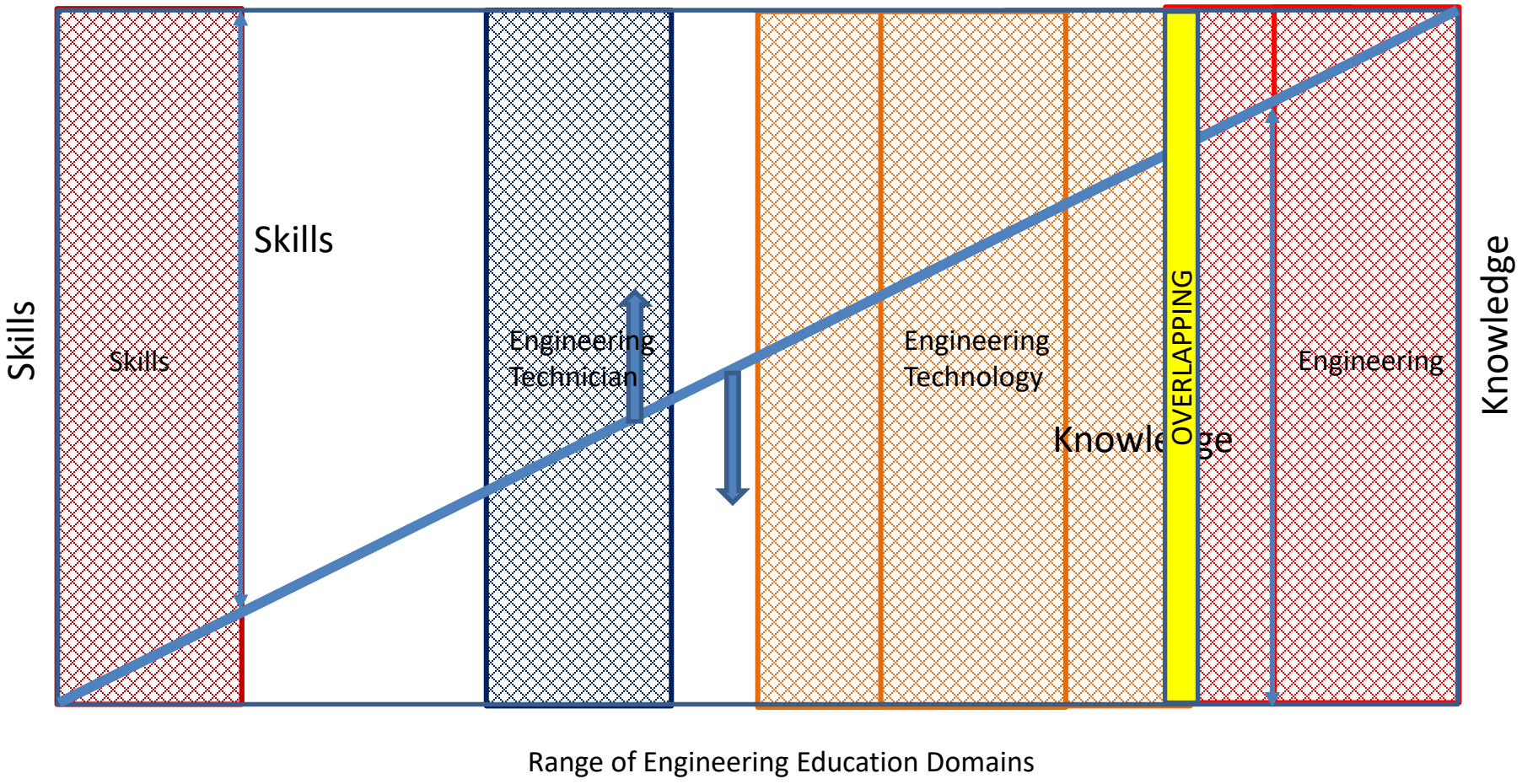
Washington Accord Graduate Attributes (PROGRAMME OUTCOMES)

Developing Curricula

WA1	Engineering Knowledge	Breadth & depth of knowledge
WA2	Problem Analysis	Complexity of analysis
WA3	Design/Development of Solutions	Breadth & uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified and coded
WA4	Investigation	Breadth & depth of investigation and experimentation
WA5	Modern Tool Usage	Level of understanding of the appropriateness of the tool
WA6	The Engineer and Society	Level of knowledge and responsibility
WA7	Environment and Sustainability	Type of solutions
WA8	Ethics	Understanding and level of practice
WA9	Individual and Team Work	Role in and diversity of team
WA10	Communication	Level of communication according to type of activities performed
WA11	Project Management and Finance	Level of management required for differing types of activity
WA12	Life-long Learning	Preparation for and depth of continuing learning

Engineering Domain




Skills
Skills
Skills
Engineering
Technician
Engineering
Technology
OVERLAPPING
Knowle ge
Engineering
Knowledge
Range of Engineering Education Domains

Depth of Knowledge Required

Engineer	Engineering Technologist	Engineering Technician
Solving →	Solving →	Solving →
Complex Engineering Problems	Defined ... Procedures, ...rocesses, Systems or Methodologies	Wide Pr... ...rocedures ...d Practices
COMPLEX PROBLEM	BROADLY DEFINED PROBLEM	WELL DEFINED PROBLEM
In-depth knowledge that allows a fundamentals-based, first principles analytical approach	Knowledge of principles with a strong emphasis on the application of developed technology	Extensive practical knowledge supported by theoretical knowledge

Complex Problem

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

Complex Problem

Difficult Decision

Uncertain Strategy

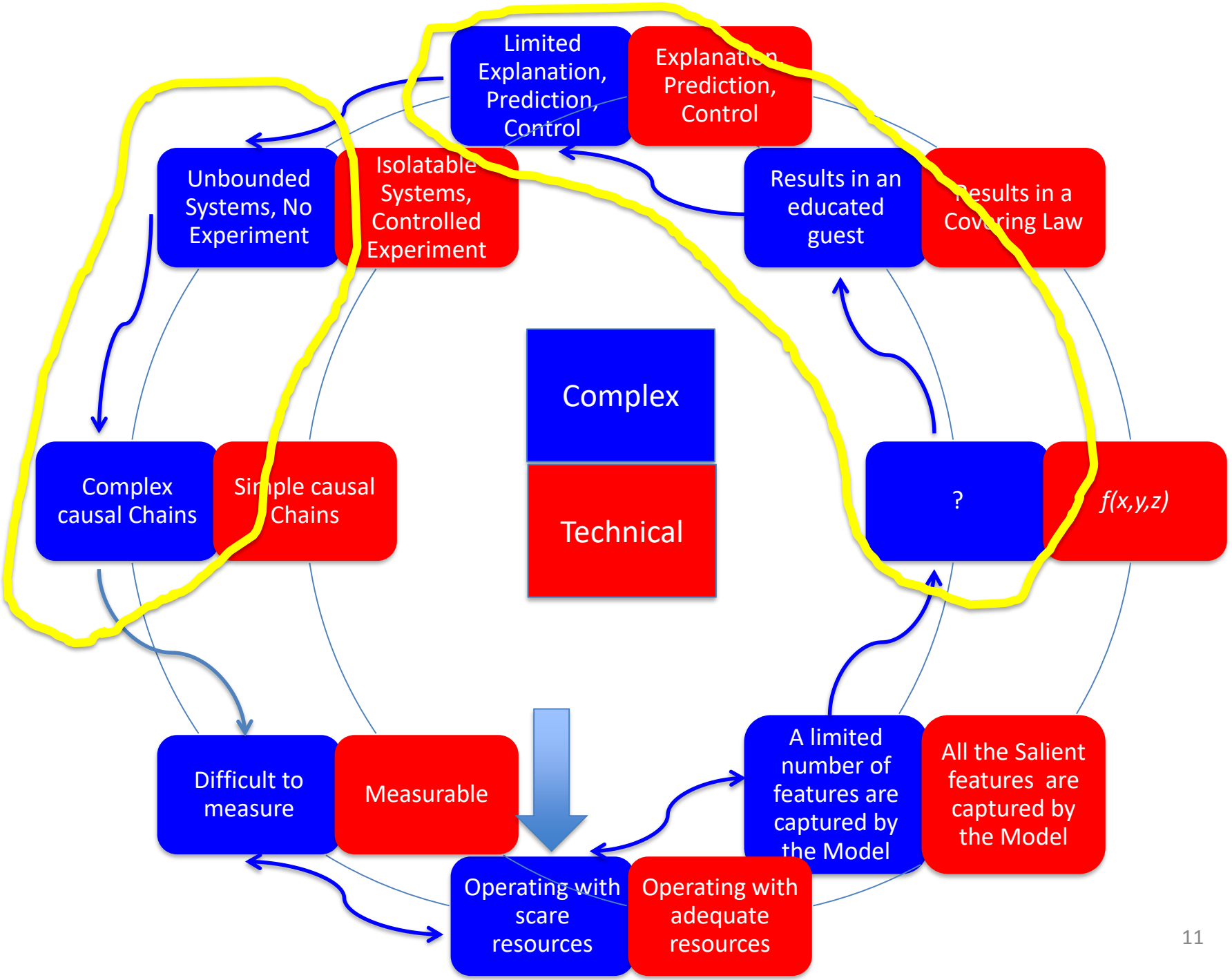
Confusing Idea

Contentious Product

Intractable Change

Difficulty & Uncertainty

- **Complexity** – the problem contains a large number of diverse, dynamic and interdependent elements
- **Measurement** – it is difficult or practically unfeasible to get good qualitative data
- **Novelty** – there is a new solution evolving or an innovative design is needed


Limited Explanation, Prediction, Control
Explanation, Prediction, Control
Unbounded Systems, No Experiment
Isolatable Systems, Controlled Experiment
Results in an educated guest
Results in a Covering Law
Complex
Technical
Complex causal Chains
Simple causal Chains
?
f(x,y,z)
Difficult to measure
Measurable
A limited number of features are captured by the Model
All the Salient features are captured by the Model
Operating with scare resources
Operating with adequate resources

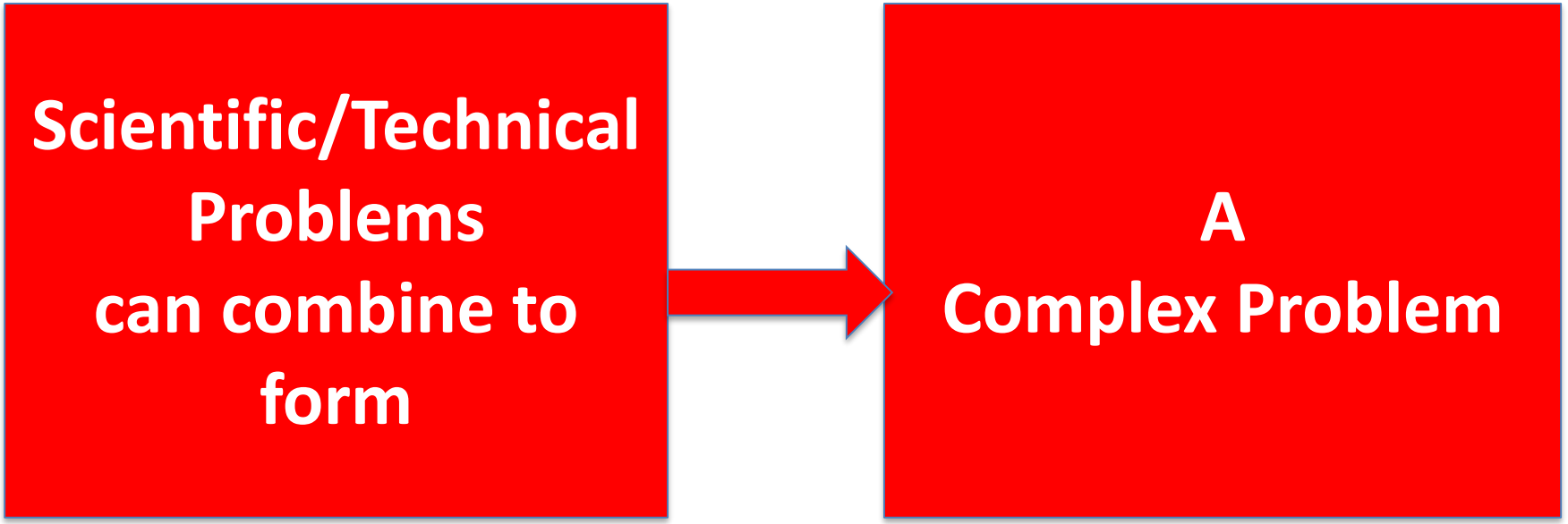
Characteristics

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


Scientific/Technical Problems can combine to form
A Complex Problem

Solving Complex Engineering Problems

Complex Engineering Problems have characteristic WP1 and some or all of WP2 to WP7. in addition EP1 and EP2 in the context of professional competencies

WP1	Depth of Knowledge required	Resolved with **in-depth** engineering knowledge (one or more of W) 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	**Beyond codes** of practice
WP6	Extent of stakeholder involvement and level of conflicting requirements	Involve **diverse groups of stakeholders** with widely **varying needs**.
WP7	Interdependence	Are **high level problems** including **many component** parts or sub-problems.
EP1	Consequences	Have **significant consequences** in a range of contexts.
EP2	Judgement	Require judgement in **decision** making

Need High Taxonomy Level ?

Knowledge Profile *(Curriculum)*

Theory-based natural **sciences**	WK1
Conceptually-based **mathematics, numerical analysis, statistics** and formal aspects of **computer and information science** to support analysis and modelling	WK2
Theory-based **engineering fundamentals**	WK3
Engineering **specialist** knowledge that provides **theoretical frameworks and bodies** of knowledge for the practice areas; much is forefront	WK4
Knowledge that supports Engineering **design** in the practice areas	WK5
Knowledge of Engineering **practice** (technology) in the practice areas	WK6
Comprehension of the role of **Engineering in society** and identified issues in engineering practice**: ethics** and professional **responsibility** of an engineer to public **safety;** the impact of engineering activity**: economic, social, cultural, environmental and sustainability**	WK7
Engagement with selected knowledge in the Research literature	WK8

Knowledge Profile

WK1
natural sciences

WK2
mathematics, numerical analysis, statistics, computer and information science

In depth for complex problem WP1

WK3
engineering fundamentals

WK4
engineering specialist knowledge

4 YEARS

In depth for complex problem WP1

WK5
engineering design

WK6
engineering practice

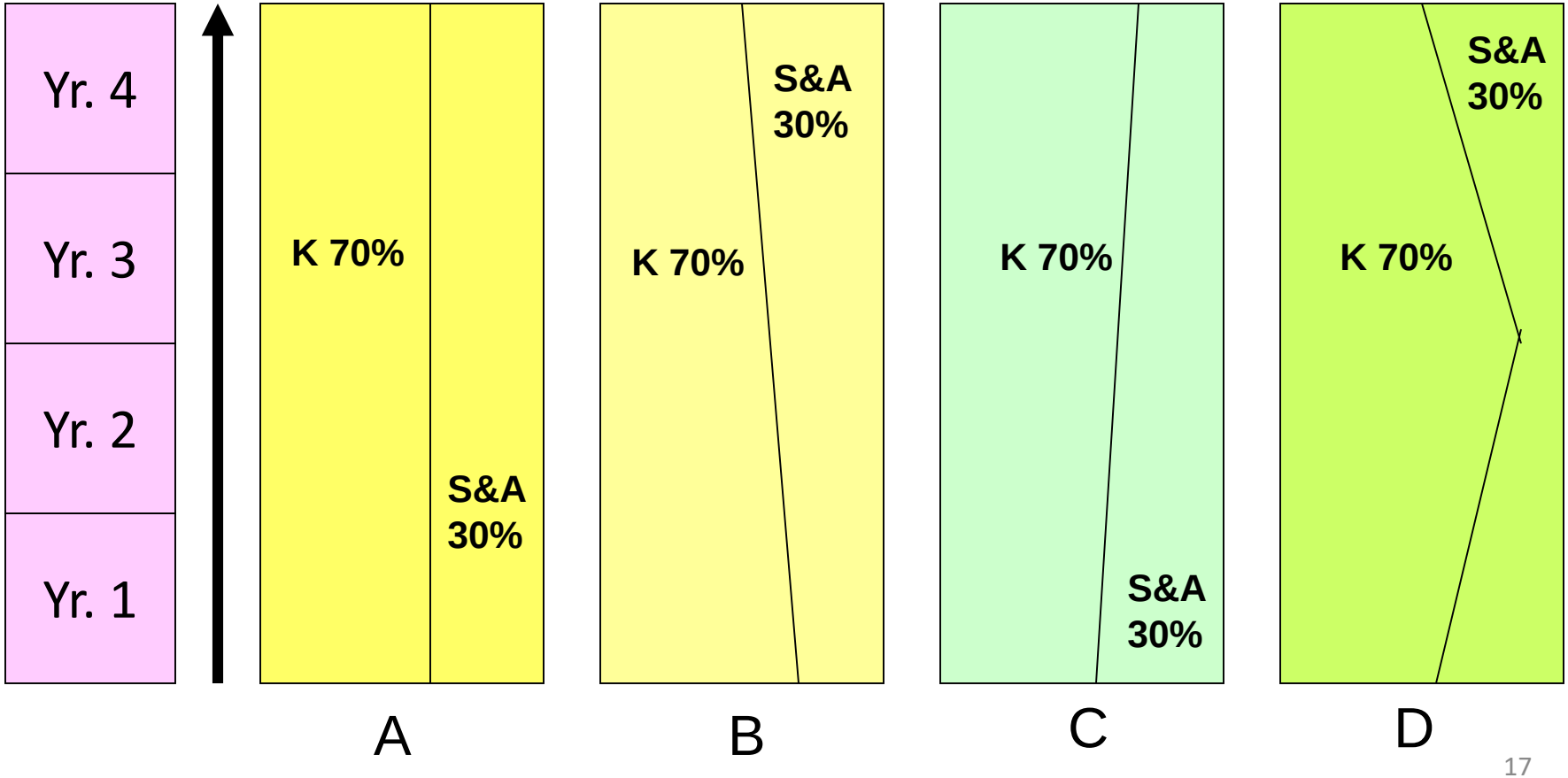
WK7
engineering in society

In depth for complex problem WP1

WK8
research literature

Exemplars of Curricula Models

Distribution of Knowledge, Skills & Attitude elements throughout the 4 years



A1:Eng Knowledge
A2:Problem Analysis
A3:Design

K1:Sci
K2:Maths
K3:Eng Fundl
K4:Eng Speclt
K5:Design

A4:Investigation
A5:Tools
A9:Ind&Team
A10:Comm
A12:Lifelong
A11:Proj Mgmt

K6:Practice
K8:Research

A6:Eng&Soc
A7:Env&Sust
A8:Ethics

K7:Eng&Soc

P1:K3,K4,K5,K6 and/or K8
P2:Conflicting
P3:No obvious soln
P4:Infrequent
P5:Beyond codes
P6:Stakeholder
P7:Interdependence

Graduate Attributes

A1	A2	A3	A4	A5	A9	A6	A7	A8
			A10	A11	A12			
K			**S**			**A**		
Knowledge (Cognitive)			Skills (Psychomotor)			Attitude (Affective)		
K1	K2	K3	K4	K5	K6	K8	K7	

A1 A2 A3

A4 A5

A6 A7

Solving Complex Engineering Problem

K3 K4 K5

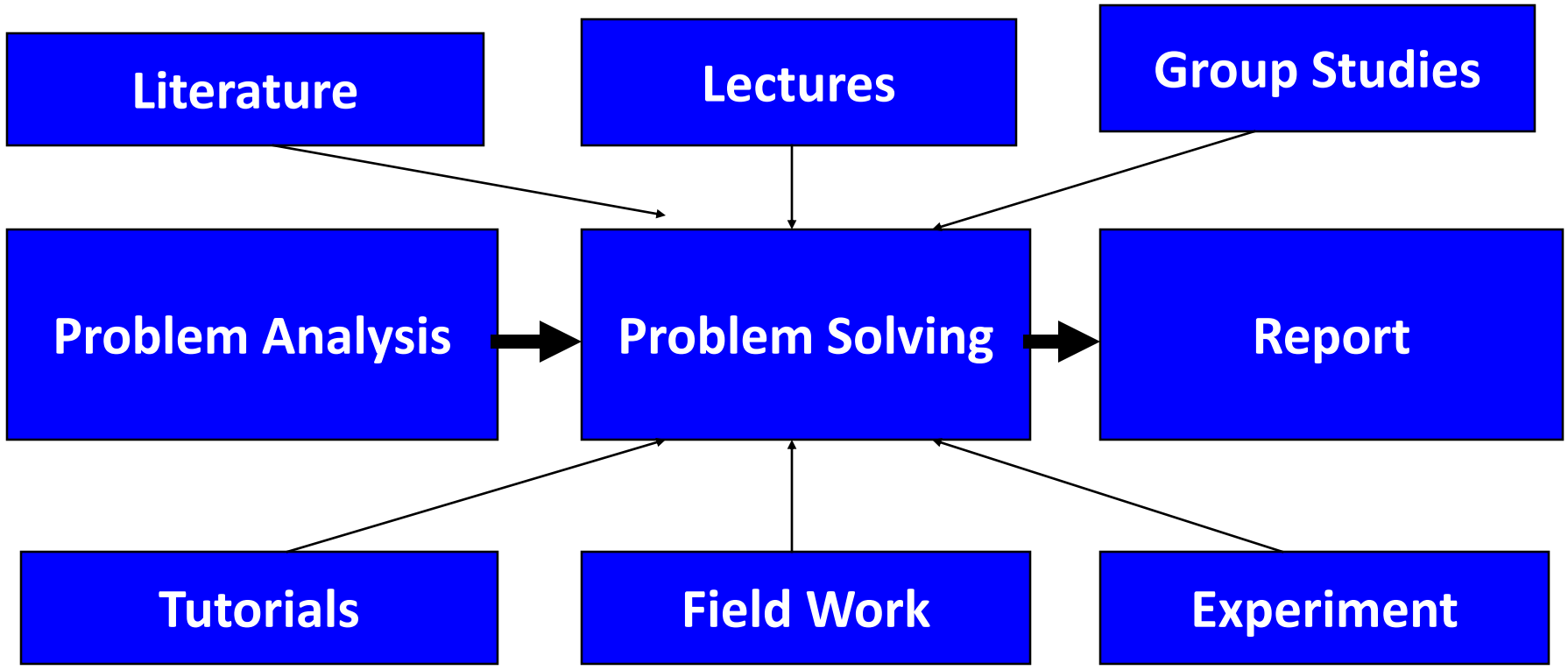
K6 and/or K8

Complex Engineering Activities

(Project-based ?)

Preamble	**Complex activities** means (engineering) activities or projects that have **some or all** of the following characteristics listed below
Range of resources	**Involve diverse resources** (people, money, equipment, materials, information and technologies).
Level of interaction	Require resolution of significant problems arising from interactions between **wide ranging** or **conflicting** technical, engineering or other issues.
Innovation	Involve creative use of engineering principles and **research-based** knowledge in **novel** ways
Consequences to society and the environment	Have **significant consequences** in a **range of contexts**, characterised by **difficulty** of prediction and mitigation.
Familiarity	Can extend **beyond previous** experiences by

Problem Organised Project Work or POPBL (Project Oriented Problem Based Learning)



Example 1: Complex Problem Solving

- Two villages in Timbuktu are **separated** from each other by a valley, at its **deepest** section about 30 metres.
- The valley is dry all the year around, except for the four months, from October to December each year, where torrential **rainfall** can flood major parts of the valley to a depth of over 12 metres in some site.
- The soil is generally **lateritic** with firm bedrock underneath. A **bridge** connecting the two villages is in a state of disrepair and has to be replaced.
- Write a project brief on how would you approach to design for the replacement bridge.
- You are limited to the use of locally available **building materials**.
- Heavy **equipment** is not available for the construction.

Aspects

- Economics
- Social
- Environment
- Ethics
- Management
- Technology
- Analysis
- Evaluation

Thinking

- Site condition
- Weather
- Available technology
- Building materials
- Design
- Costing
- Scheduling

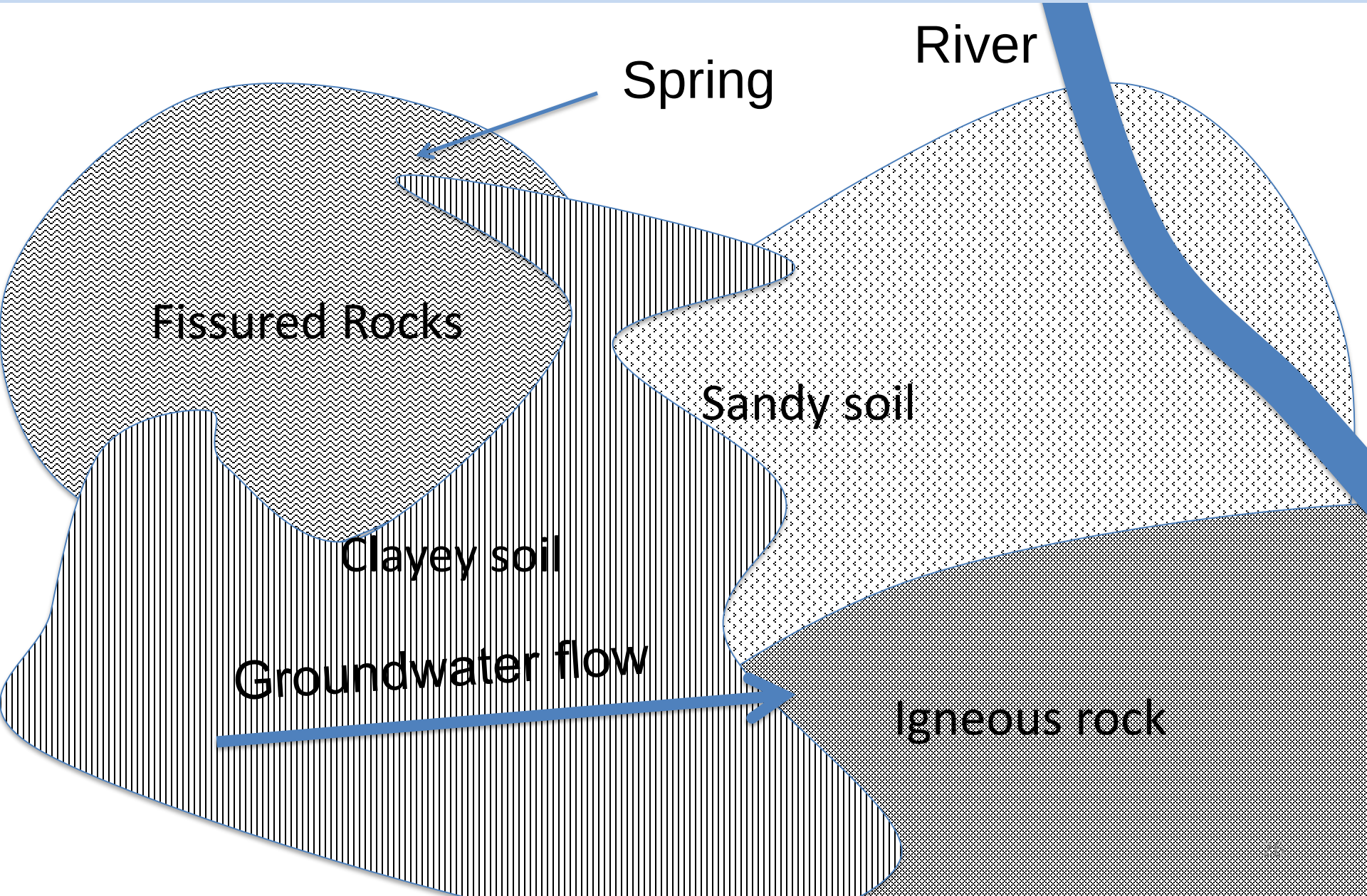
Solutions?

- Problem solving skills
- Formulate the problem
- Literature
- Experiment?

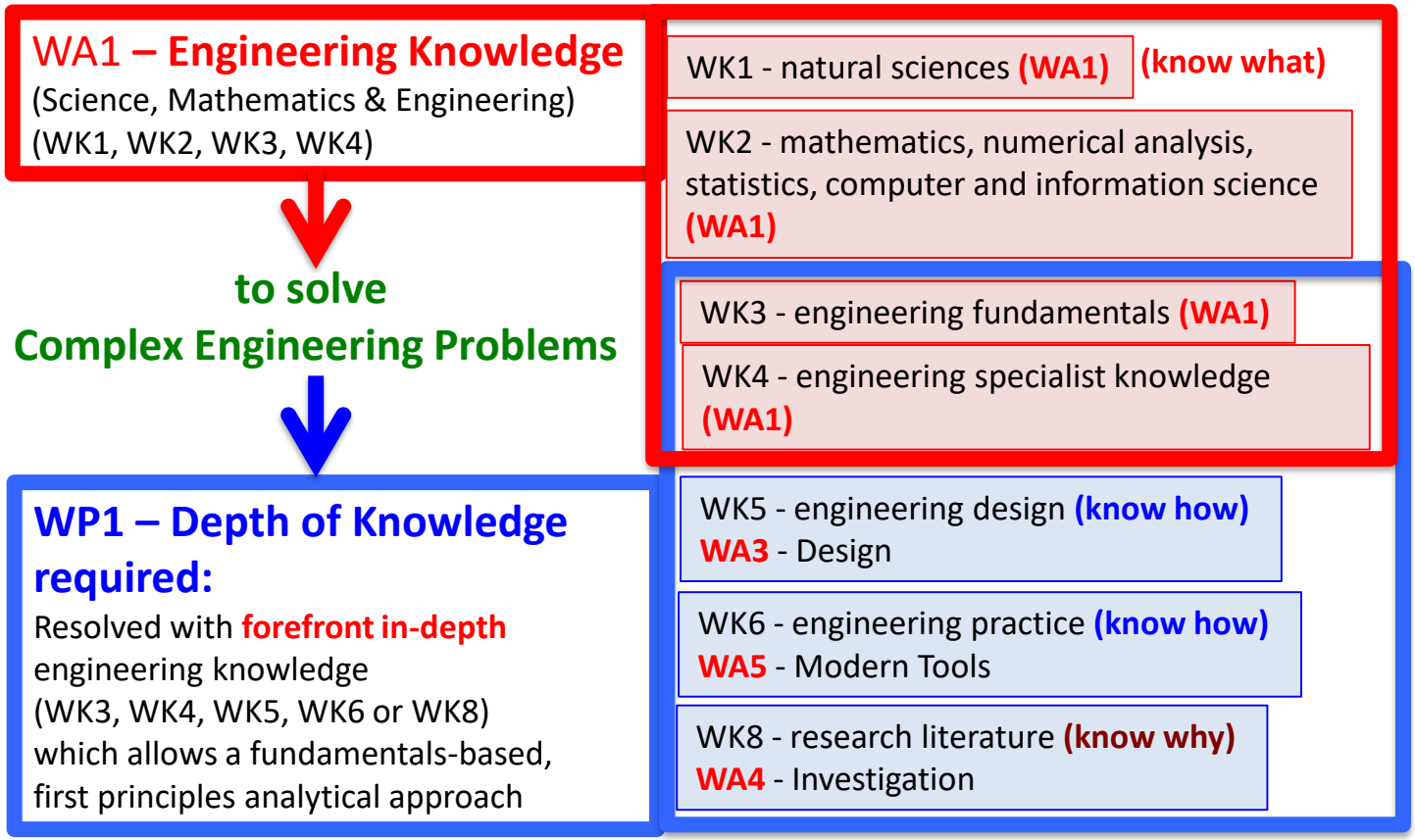
Assessment

- Report – style and content (flow)
- Display – attractive ?
- Viva / Articulation
- Teamwork
- Management – scheduling

Example 2: Complex Problem Solving



WA – WK – WP Relationships



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to solve
Complex Engineering Problems

WK1 - natural sciences **(WA1)**

WK2 - mathematics, numerical analysis, statistics, computer and information science **(WA1)**

WP1 – Depth of Knowledge required:

Resolved with **forefront in-depth** engineering knowledge (WK3, WK4, WK5, WK6 or WK8) which allows a fundamentals-based, first principles analytical approach

WK3 - engineering fundamentals **(WA1)**

WK4 - engineering specialist knowledge **(WA1)**

WK5 - engineering design
WA3 - Design

WK6 - engineering practice
WA5 - Modern Tools

WK8 - research literature
WA4 - Investigation

WP2	**Range of conflicting requirements**
WP3	**Depth of analysis required**
WP4	**Familiarity of issues**
WP5	**Extent of applicable codes**
WP6	**Extent of stakeholder involvement and level of conflicting requirements**
WP7	**Interdependence**
EP1	**Consequences**
EP2	**Judgement**

Some or all
WP2 – WP7, EP1 & EP2

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WP2	**Range of conflicting requirements**
WP3	**Depth of analysis required**
WP4	**Familiarity of issues**
WP5	**Extent of applicable codes**
WP6	**Extent of stakeholder involvement and level of conflicting requirements**
WP7	**Interdependence**
EP1	**Consequences**
EP2	**Judgement**

WK7 - engineering in society
WA6 - engineer & society
WA7 - environment & sustainability
WA8 - ethics

Breadth

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Design Course

WK1 - natural sciences **(WA1)**

WK2 - mathematics, numerical analysis, statistics, computer and information science **(WA1)**

WP1 – Depth of Knowledge required:

Resolved with **forefront in-depth** engineering knowledge (WK3, WK4, WK5, WK6 or WK8) which allows a fundamentals-based, first principles analytical approach

WK3 - engineering fundamentals **(WA1)**

WK4 - engineering specialist knowledge **(WA1)**

WK5 - engineering design
WA3 - Design

WK6 - engineering practice
WA5 - Modern Tools

WK8 - research literature
WA4 - Investigation

WP2	**Range of conflicting requirements**
WP3	**Depth of analysis required (WA2)**
WP4	**Familiarity of issues**
WP5	**Extent of applicable codes**
WP6	**Extent of stakeholder involvement and level of conflicting requirements WK7 (WA6, WA7, WA8)**
WP7	**Interdependence**
EP1	**Consequences**
EP2	**Judgement**

WK7 - engineering in society
WA6 - engineer & society (WK7)
WA7 - environment & sustainability (WK7)
WA8 – ethics (WK7)

WA2 - Problem Analysis (WK 1-4)
WA9 - Individual and Team Work
WA10 - Communication
WA11 - Project Management and Finance
WA12 - Life-long Learning

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How does complexity relates to curriculum?

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

Conclusion

- Adequate knowledge profile
- Right taxonomy
- Demonstrate outcomes (solving complex problem)

Thank You

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Appendix

PROGRAMME OUTCOME

(i) Engineering Knowledge

(WA1) Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialisation to the solution of **complex** engineering problems; **(WK1 to WK4)**

WA = Programme Outcome
WK = Knowledge Profile = Curriculum

PROGRAMME OUTCOME

(ii) **Problem Analysis - Complexity of analysis**
(WA2) Identify, formulate, research literature and analyse **complex** engineering problems reaching substantiated conclusions using **first principles** of mathematics, natural sciences and engineering sciences **(WK1 – WK4)**

PROGRAMME OUTCOME

(iii) Design/Development of Solutions – Breadth and uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified or codified

(WA3) Design solutions for **complex** engineering problems and design systems, components or processes that **meet specified needs** with appropriate consideration for **public health and safety, cultural, societal, and environmental considerations (WK5)**

PROGRAMME OUTCOME

(iv) **Investigation - Breadth & Depth of Investigation & Experimentation**
(WA4) Conduct investigation of **complex** problems using **research based knowledge (WK8)** and **research methods** including **design of experiments, analysis and interpretation of data, and synthesis of information** to provide valid conclusions

PROGRAMME OUTCOME

(v) **Modern Tool Usage - Level of understanding of the appropriateness of the tool**
(WA5) Create, select and apply **appropriate techniques, resources, and modern engineering and IT tools**, including **prediction** and **modelling**, to **complex** engineering problems, with an understanding of the limitations. **(WK6)**

PROGRAMME OUTCOME

(vi) **The Engineer and Society - Level of knowledge and responsibility**
(WA6) Apply reasoning informed by contextual knowledge 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)**

PROGRAMME OUTCOME

(vii) **Environment and Sustainability - Type of solutions**
(WA7) Understand and evaluate the sustainabilty and **impact of** professional engineering work in the **solutions** of **complex** engineering problems in **societal and environmental** contexts (demonstrate knowledge of and need for sustainable development) **(WK7)**

PROGRAMME OUTCOME

(viii) **Ethics - Understanding and level of practice**
(WA8) Apply ethical principles and **commit** to professional ethics and responsibilities and norms of engineering practice. **(WK7)**

PROGRAMME OUTCOME

(x) **Individual and Team Work – Role in and diversity of team**
(WA9) Function effectively as an individual, and as a member or leader **in diverse teams and in multi-disciplinary settings**

PROGRAMME OUTCOME

(ix) **Communication – Level of communication according to type of activities performed**
(WA10) 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**

PROGRAMME OUTCOME

(xi) Project Management and Finance – Level of management required for differing types of activity
(WA11) Demonstrate knowledge and understanding of engineering and management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments

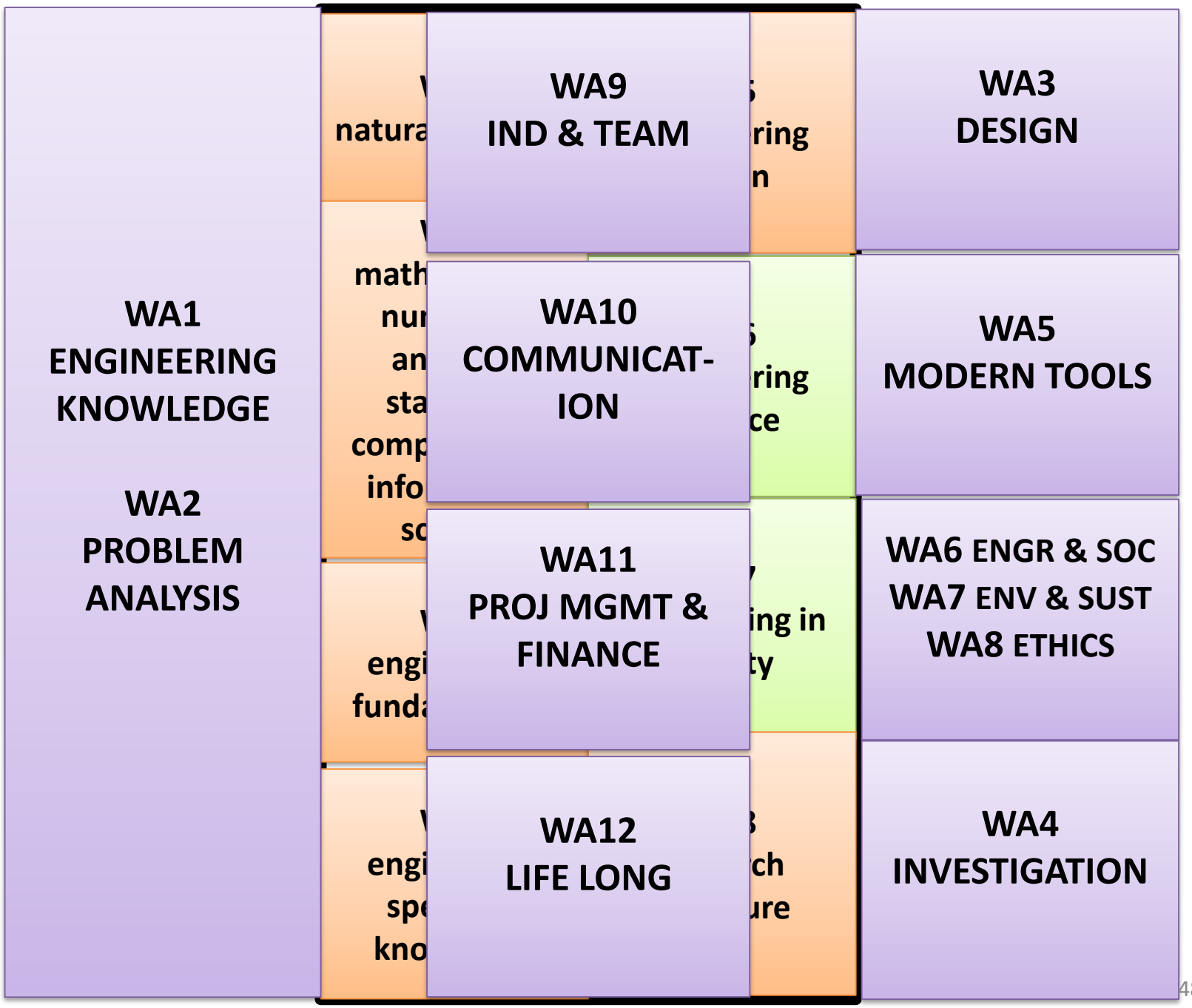
PROGRAMME OUTCOME

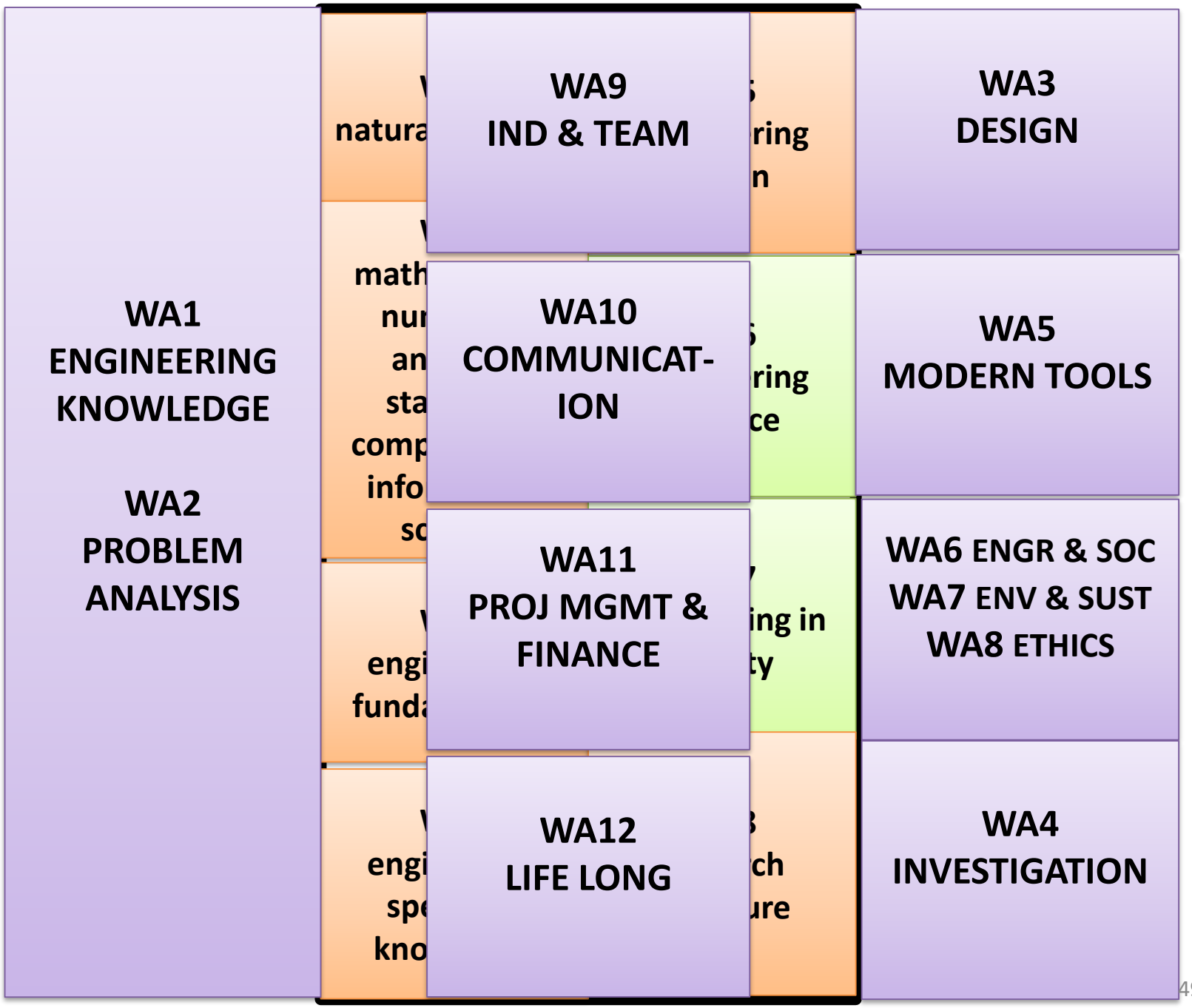
(xii) **Life-long Learning – Preparation for and depth of continuing learning**
(WA12) Recognise the need for, and have the preparation and ability to **engage in independent** and **life-long learning** in the **broadest context of technological change**

PROGRAMME OUTCOME

(i) Engineering Knowledge

Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialisation to the solution of **complex** engineering problems;


WA1
ENGINEERING
KNOWLEDGE
WA2
PROBLEM
ANALYSIS
WA9
IND & TEAM
WA3
DESIGN
WA10
COMMUNICAT-
ION
WA5
MODERN TOOLS
WA11
PROJ MGMT &
FINANCE
WA6 ENGR & SOC
WA7 ENV & SUST
WA8 ETHICS
WA12
LIFE LONG
WA4
INVESTIGATION


WA1
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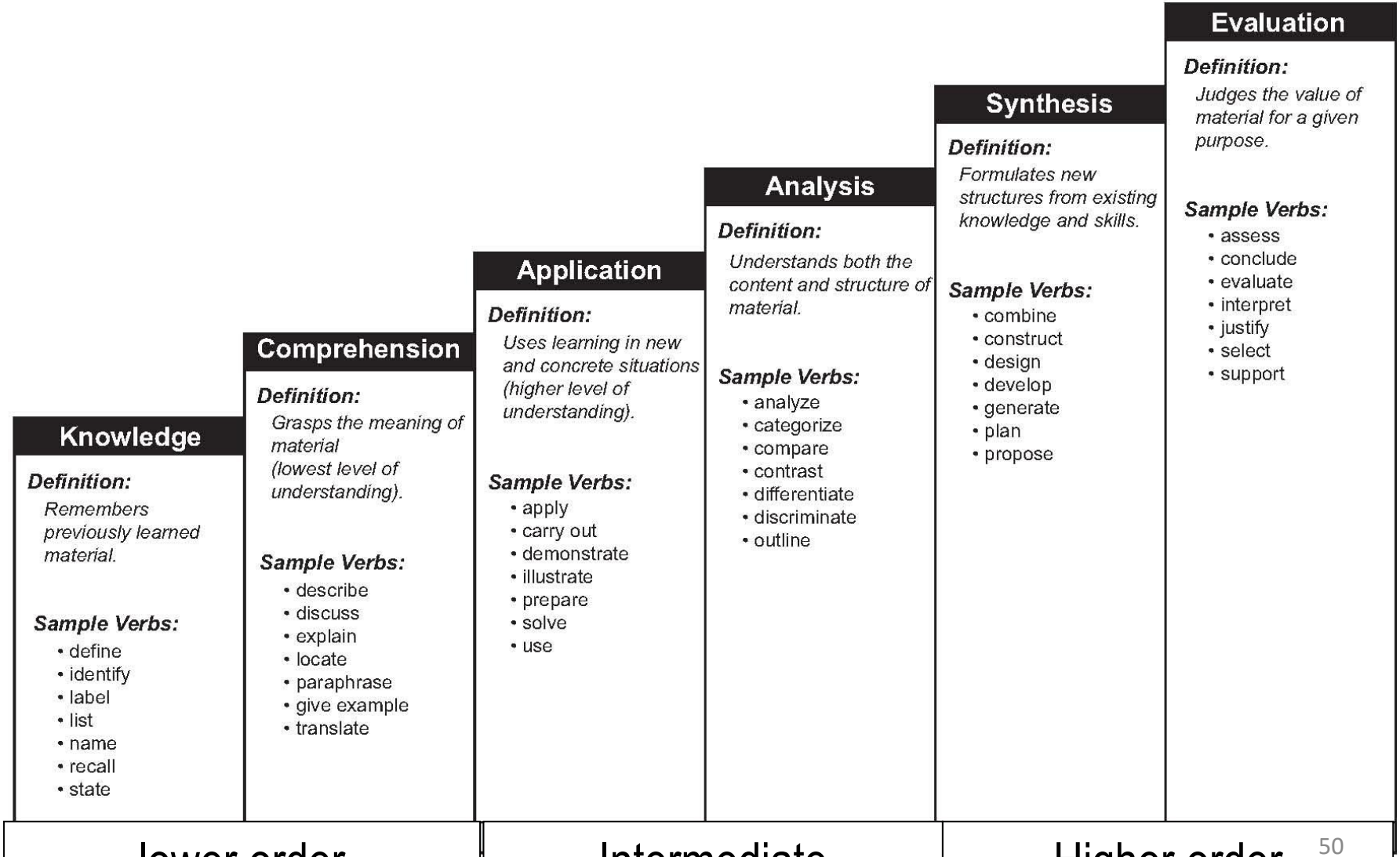
WA8 ETHICS
WA12
LIFE LONG
WA4
INVESTIGATION

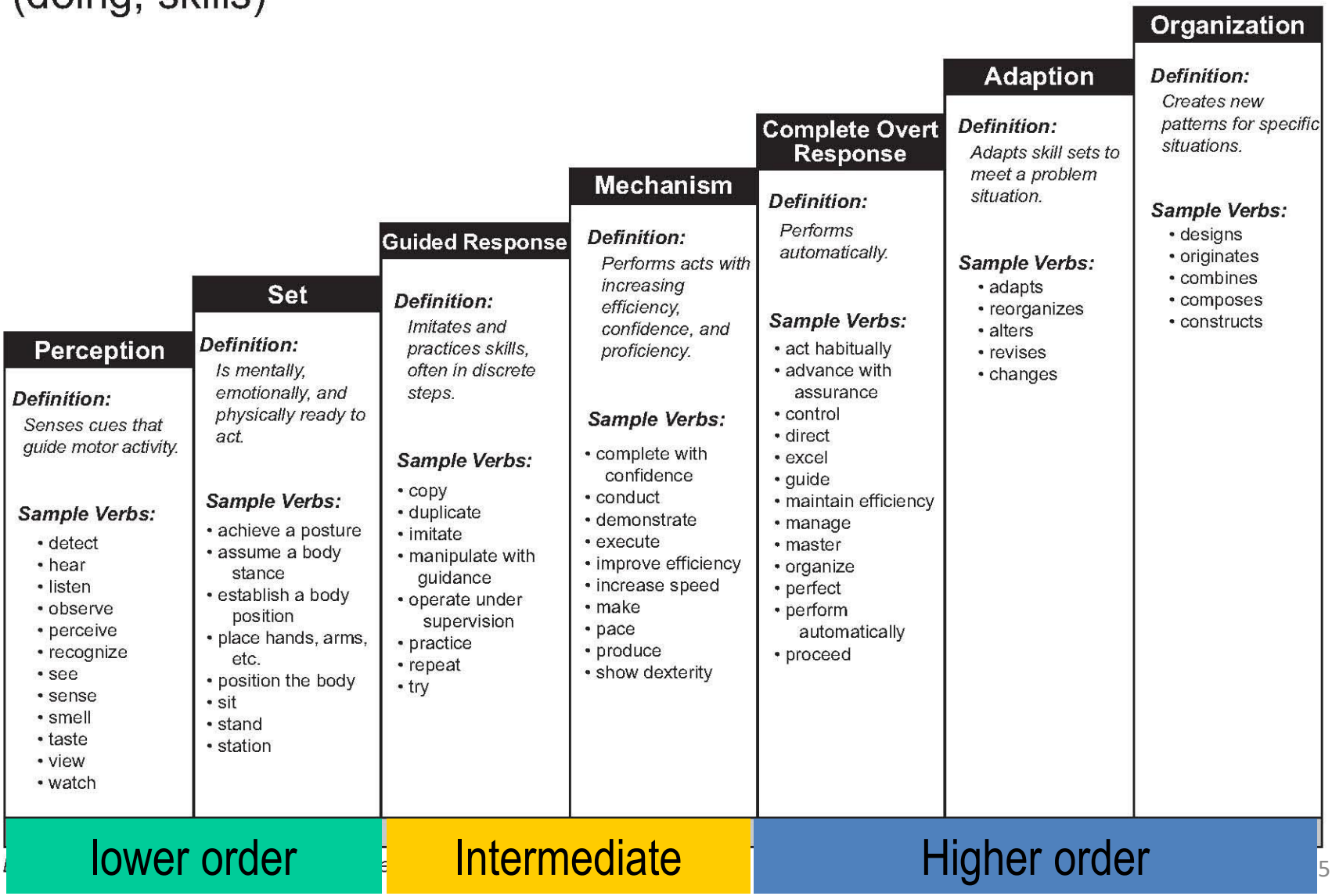
Cognitive Domain

(thinking, knowledge)



Psychomotor Domain

(doing, skills)



Affective Domain

(feeling, attitudes)