Training Workshop

on

Introduction to Outcome-based education: Teaching-learning and assessment

Organized By:

Institutional Quality Assurance Cell (IQAC), BUET

Date: March 7, 2024 (Thursday)

A. S. M. A. Haseeb

Nanomaterials ad Ceramic Engineering Dept., BUET, Dhaka

Topics

1. Quality Assurance and Accreditation in Higher Education
2. Accreditation of Engineering Education: Washington Accord Framework
3. Essentials of Outcome Based Curriculum Design as per WA
4. Outcome Based Education: Basics
5. Implementation of Outcome Based Education

Quality Assurance and Accreditation in Higher Education

A. S. M. A. Haseeb
Nanomaterials ad Ceramic Engineering Dept., BUET, Dhaka

Why quality assurance in higher education ?

- Maintain standards
- Accountability
- Competition
- Credibility, prestige and status
- Image and visibility
- Customer satisfaction
- Improve employee morale and motivation

National Assessment and Accreditation Council

Higher Education Matters

- Student numbers are exploding around the world, as there has never been a greater need for a good tertiary education.
- Emerging economies will have around 63 million more university students in 2025 and the number worldwide is expected to more than double to 262 million by the same year

- **Global student population**
  - 1900: 0,5 mill.
  - 1950: 6,3 mill.
  - 1970: 28,6 mill.
  - 2000: 99,5 mill.
  - 2005: 139 mill.
  - 2013: 199 mill.
  - 2035: 520 mill?

https://worldpopulationreview.com/country-rankings/most-educated-countries

- **Percentage of Citizens Who Have Completed Tertiary Education (by Generation) - OECD 2021**

Ranking	55-64 year-olds	%	25-34 year-olds	%
1	Russia	50.3	South Korea	69.8
2	Canada	50.0	Canada	64.4
3	Israel	46.1	Russia	62.1
4	Japan	44.5	Japan	61.5
5	United States	44.3	Ireland	58.4
6	Finland	42.9	Luxembourg	58.2
7	United Kingdom	39.4	Lithuania	56.2
8	Estonia	39.2	United Kingdom	55.8
9	Australia	36.3	Australia	54.6
10	Switzerland	34.7	Switzerland	53.0

Quality Assurance of Higher Education Through **Accreditation**

"…the process of reviewing colleges, universities, institutions and programs to judge their educational quality – how well they serve students and society…"

Council for Higher Education Accreditation (CHEA)

Assures that a neutral, external party (accrediting organization) has reviewed the quality of education provided and has found it to be satisfactory, based upon appropriate peer expertise.

Accreditation of higher education is both an old a new phenomenon

- Higher education accreditation in the United States begun in 1880s
- Currently more than 50 accreditation organizations under US Department of Education and CHEA
- Accreditation bodies in the US are decentralized

1. Regional accreditation
2. National accreditation
3. Specialized and professional accreditation
4. Religious accreditation

Accreditation of Engineering Education

US 1932

- Accreditation Board for Engineering and Technology (ABET)
- **1932** → Engineers' Council for Professional Development (ECPD)

France 1934

- Commission des Titres d'Ingénieur (CTI) Engineering Degree Commission
- **1934** → one of the first, accreditation boards in France and Europe

UK 1964

- The Engineering Council UK (EC^{UK})
- **1964** → Joint Council of Engineering Institutions

Recent resurgence of worldwide activities on accreditation of engineering programmes

Regional	International
• EU → EUR-ACE Project for Eng. Education, Bologna Process for higher education • Middle east → Gulf Cooperation Council Accreditation Board for Engineering and Technology (GABET) • Asia • Africa	• Internationalization of accreditation, multilateral dimensional • Most prominent international effort → **<u>Washington Accord</u>**

FULL SIGNATORIES OF WASHINGTON ACCORD

- **Korea** - (2007)
- **Russia** - (2012)
- **Malaysia** - (2009)
- **China** - (2016)
- **South Africa** - (1999)
- **New Zealand** - (1989)
- **Australia** - (1989)
- **Canada** - (1989)
- **Ireland** - (1989)
- **Hong Kong China** - (1995)
- **Chinese Taipei** - (2007)
- **Singapore** - (2006)
- **Sri Lanka** - (2014)
- **Japan** - (2005)
- **India** - (2014)
- **United States** - (1989)
- **Turkey** - (2011)
- **United Kingdom** - (1989)
- **Costa Rica** - (2020)
- **Mexico** - (2022)
- **Pakistan** - (2017)
- **Peru** - (2018)
- **Indonesia** - (2022)

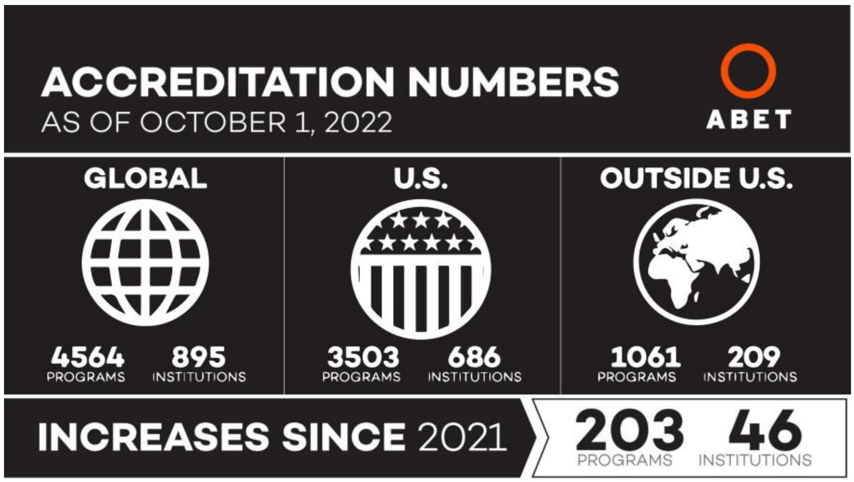
ABET: Accreditation Board for Engineering and Technology

PROVISIONAL SIGNATORIES OF WASHINGTON ACCORD

- **Chile** - Provisional Status Approved in 2018.
- **Thailand** - 2019.
- **Bangladesh** - 2016.
- **Philippines** - 2016.
- **Myanmar** - 2019.
- **Saudi Arabia** - 2022
- **Nigeria** - 2023

BAETE: Board of Accreditation for Engineering and Technical Education ttps://acrome.net/post/experiment-systems-for-abet

ABET accreditation of engineering programmes



Top Engineering Schools of US are accredited by ABET

- Massachusetts Institute of Technology
- Stanford University
- University of California, Berkeley
- Harvard University
- California Institute of Technology
- Georgia Institute of Technology
- University of California, Los Angeles
- Princeton University
- Purdue University
- Carnegie Mellon University
- University of Illinois at Urbana - Champaign
- Cornell University
- University of Michigan
- University of Texas at Austin
- Northwestern University
- Pennsylvania State University
- Texas A&M University
- Pennsylvania State University
- Virginia Polytechnic Institute and State University
- University of Chicago

https://facts.mit.edu/accreditation/

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Accreditation

MIT is accredited by the New England Commission of Higher Education.

Inquiries regarding MIT's accreditation status may be submitted to MIT at accreditation@mit.edu or directly to the commission:

New England Commission of Higher Education
301 Edgewater Place, Suite 210
Wakefield, MA 01880
telephone: 781-425-7785
email: info@neche.org

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https://cee.mit.edu/education/undergraduate/

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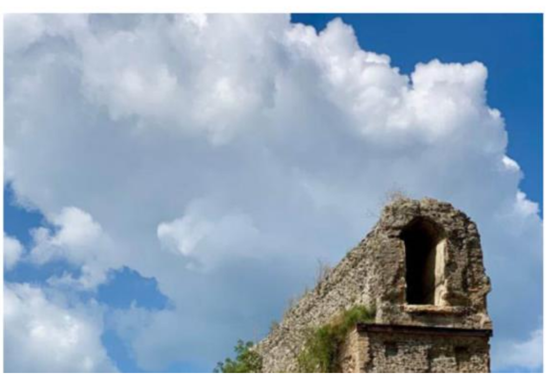

Welcome to Course 1

Our core mission is to educate, inside and outside the classroom.

MIT CEE equips you with the fundamental skills to succeed as an engineer in today's complex world through our general engineering ABET accredited undergraduate program. Grounded in science and engineering, we understand the world, invent and lead with creative design. Our students pursue education in classrooms, laboratories, design subjects, as well as field subjects. Many of our students pursue opportunities such as

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https://ir.mit.edu/abet-enrollments

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ABET ENROLLMENTS

Undergraduate Enrollment in ABET-accredited programs

Undergraduate Enrollment in ABET-accredited programs

Department Name	Program	student yea..	Academic Year 2015	2016	2017	2018	2019	2020	2021	2022	2023
		5	2	2	1	1	1	1			2
	Chemical-Biological Engineering, Course 10B	2	19	18	27	14	14	18	13	21	12
		3	23	21	18	26	12	14	16	13	18
		4	23	21	19	12	23	10	16	14	14
⋮											
		5			2	1	2		2	2	4
Electrical Eng & Computer Sci	Electrical Science and Engineering, Course 6-1	2	27	25	13	19	25	10	16	16	13
		3	27	31	28	12	22	25	8	13	11
		4	21	28	31	22	11	20	21	9	12
		5	3	2	6	6	3	1	8	5	4
	Electrical Engineering and Computer Science, Course 6-2	2	184	160	159	127	132	124	119	98	116
		3	143	162	150	141	128	123	112	143	94
		4	115	107	123	106	100	106	97	105	116
		5	11	12	8	6	9	6	10	7	7
	Computer Science and Engineering, Course 6-3	2	170	188	216	258	210	216	234	223	263
		3	175	206	204	257	280	243	250	266	251
		4	139	190	229	228	266	255	238	226	243

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Accreditation Organization

	General	Specialized, Programme Based
Bangladesh	BAC	BAETE
Malaysia	Malaysian Qualification Agency	Engineering Accreditation Council
US	Many…	ABET

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"Quality is not an act, it is a habit"

- Aristotle

Summary

Accreditation of Engineering Education: Washington Accord Framework

A. S. M. A. Haseeb
Nanomaterials ad Ceramic Engineering Dept., BUET, Dhaka

International Engineering Alliance:

Umbrella organization of international engineering societies/bodies

- Deals with both **engineering education** and **engineering practice**
- Covers whole spectrum of engineering → all levels: **Engineers**, **Technologists**, **Technicians**

As for engineering education:

IEA establishes & enforces internationally-benchmarked standards → "entry level" competence to practise engineering

Equivalence and international recognition for educational programmes for

INTERNATIONAL ENGINEERING ALLIANCE

Engineers	**Washington Accord 1989**
Technologists	**Sydney Accord 2001**
Technicians	**Dublin Accord 2002**

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Board of Accreditation for Engineering and Technical Education (BAETE)

Three stages for professional engineer to qualify for independent practice or licensure/registration:

1. **Education stage**, provided by externally accredited programme of four/five years
2. **Period of supervised training** while gaining experience in engineering practice
3. Individuals have **competence assessed** → to be eligible as competent engineering practitioner

A. S. M. A. Haseeb, NCE Dept., BUET 5

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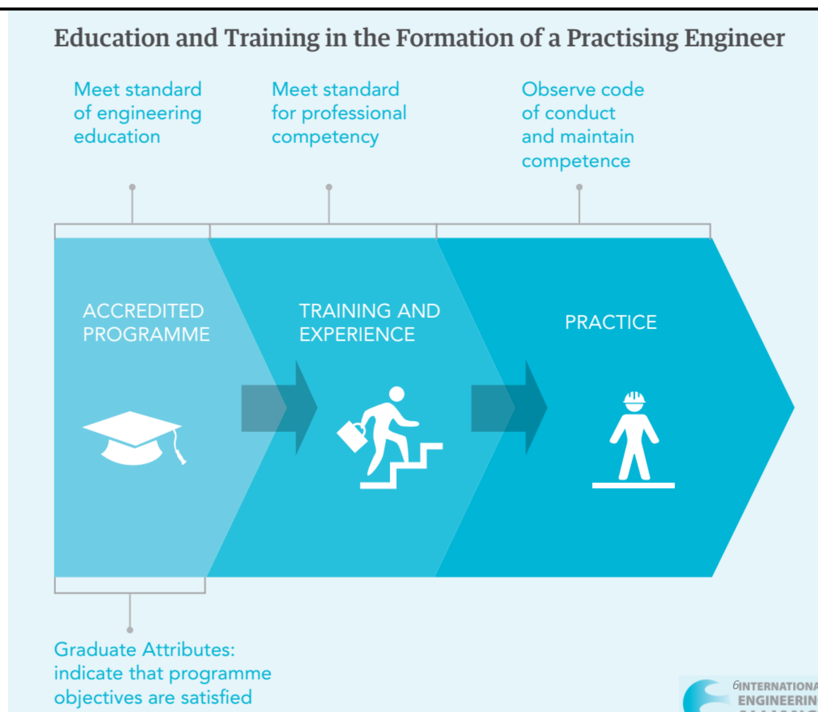
…**externally accredited** programme of four or five years …

…followed by a period of supervised training while gaining experience in engineering practice.

Washington Accord
…recognizes the "**substantial equivalency**" of systems to assess that **graduates** of accredited programs are **prepared to practice engineering at the entry level to the profession**…



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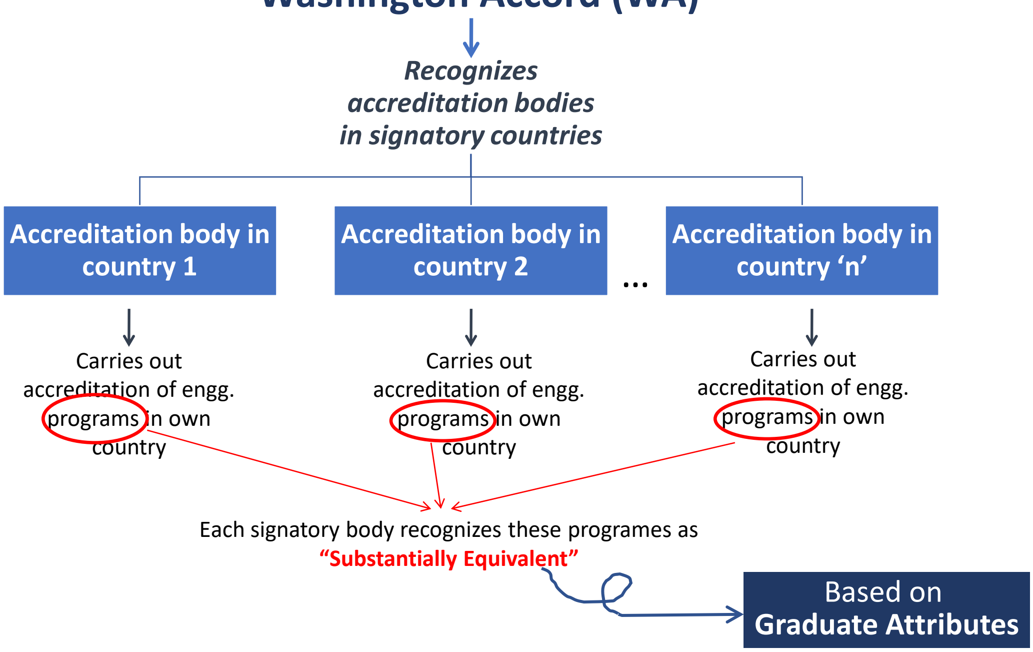
Essence of Washington Accord

*...recognizes the "**substantial equivalency**" of systems to assess that **graduates** of accredited programs are **prepared to practice engineering at the entry level to the profession**...*

Washington Accord (WA)



Difference among
Engineers, Technologists and Technicians

In term of Problem Analysis ….

Engineers (Washington Accord)	Technologists (Sydney Accord)	Technicians (Dublin Accord)
Identify, formulate, research literature and solve ***complex engineering problems*** reaching substantiated conclusions using ***first principles of mathematics and engineering sciences***	Identify, formulate, research literature and solve ***broadly-defined engineering problems*** reaching substantiated conclusions using *analytical tools appropriate to their discipline or area of specialization*	Identify and solve ***well-defined engineering problems*** reaching substantiated conclusions using *codified methods of analysis specific to their field of activity*

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Difference among Engineers, Technologists and Technicians…

Engineers *Solve* **Complex Problems**	*Technologists* *Solve* **Broadly-defined Problems**	*Technicians* *Solve* **Well-defined Problems**
Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	Can be solved by well-proven analysis techniques	Can be solved in standardized ways

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Graduate Attributes

of engineering graduates as prescribed by Washington Accord

Examples of attributes expected of a graduate

- Generic → for all engineering disciplines
- Reference point against which substantial equivalence are assessed
- Intended to develop outcomes-based accreditation criteria for use by respective jurisdictions

- What graduates should **know**
- **Skills** they should demonstrate
- **Attitudes** they should possess

Graduate Attributes, contd.

- Defining characteristic of professional engineering → ability to work with complexity and uncertainty (since no real engineering project is exactly same as any other)

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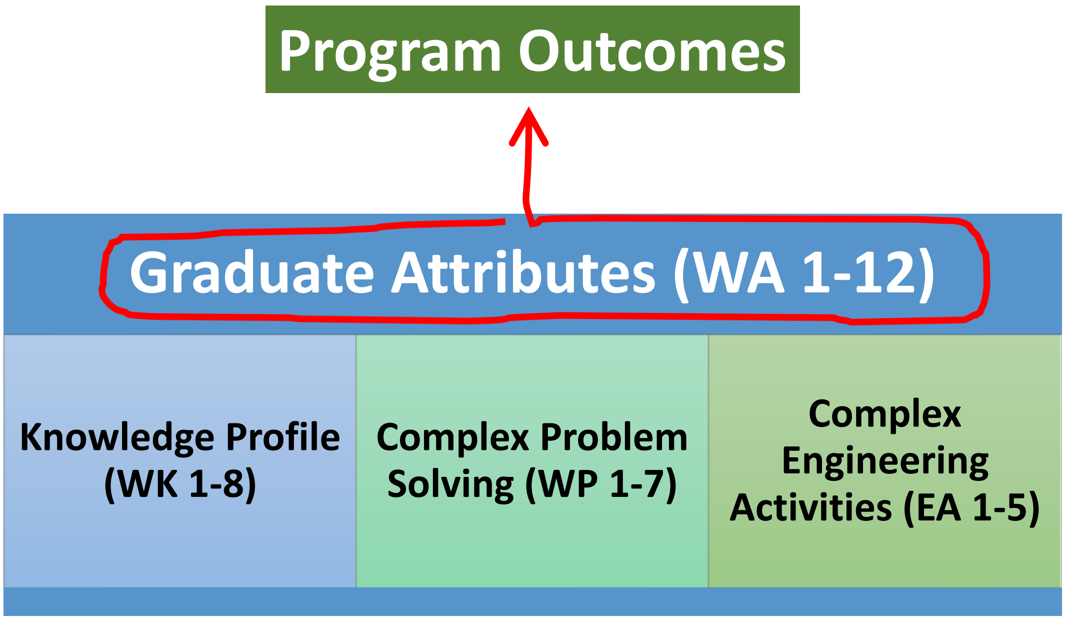
Notions of complex engineering problems and complex problem solving



Graduate Attributes

Engineering knowledge **WA1**	WA1: Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialisation as specified in WK1 to WK4 respectively to the solution of complex engineering problems.
WA2 Problem 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 to WK4).
WA3 Design/ development of solutions	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).

Graduate Attributes, contd.

WA4 Investigation	WA4: Conduct investigations 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.
WA5 Modern tool usage	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).
WA6 The engineer and society	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).

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Graduate Attributes, contd.

WA7 Environment and sustainability	WA7: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts (WK7).
WA8 Ethics	WA8: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice (WK7).
WA9 Individual and teamwork	WA9: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
WA10 Communication	WA10: Communicate effectively on complex engineering activities with the engineering community and 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.

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Graduate Attributes, contd.

Project management and finance **WA11**	WA11: Demonstrate knowledge and understanding of engineering 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 multi-disciplinary environments.
WA12 Life-long 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.

Graduate Attributes (WA 1-12)

Knowledge Profile (WK 1-8)	Complex Problem Solving (WP 1-7)	Complex Engineering Activities (EA 1-5)

Knowledge Profile

No.	Knowledge Profile (WK)	Characteristics
WKI	Natural sciences	Systematic theory based understanding of the natural sciences applicable to the discipline.
WK2	Mathematics	Conceptually based mathematic, numerical analysis, statistic and formal aspects of computer and information science to support analysis and modelling applicable to the discipline.
WK3	Engineering fundamentals	A systematic, theory based formulation of engineering fundamental 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.

Knowledge Profile, contd.

No.	Knowledge Profile (WK)	Characteristics
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.

Graduate Attributes (WA 1-12)

Knowledge Profile (WK 1-8)	Complex Problem Solving (WP 1-7)	Complex Engineering Activities (EA 1-5)

Attributes of **complex engineering problems:**

At least some may be encountered within a professional engineering education programme

Attributes of complex engineering problems

Depth of knowledge required **WP1**	WP1: 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.
Range of conflicting requirements **WP2**	WP2: Involve wide-ranging or conflicting technical, engineering and other issues.
Depth of analysis required **WP3**	WP3: Have no obvious solution and require abstract thinking and originality in analysis to formulate suitable models.
Familiarity of issues **WP4**	WP4: Involve infrequently encountered issues.

Complex engineering problems, contd.

Extent of applicable codes **WP5**	WP5: Outside problems encompassed by standards and codes of practice for professional engineering.
Extent of stakeholder involvement and needs **WP6**	WP6: Involve diverse groups of stakeholders with widely varying needs.
Interdependence **WP7**	WP 7: High level problems including many component parts or sub-problems.

Graduate Attributes (WA 1-12)

Knowledge Profile (WK 1-8)	Complex Problem Solving (WP 1-7)	Complex Engineering Activities (EA 1-5)

Attributes of **complex engineering activities**:

some might be encountered by an engineering undergraduate, e.g., during capstone design or a period of industry experience

Attributes of complex engineering activities

Range of resources	EA1	EA1: Involve the use of diverse resources (and for this purpose resources include people, money, equipment, materials, information and technologies).
Level of interactions	EA2	EA2: Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues.
Innovation	EA3	EA3: Involve creative use of engineering principles and research-based knowledge in novel ways.
Consequences to society and the environment	EA4	EA4: Have significant consequences in a range of contexts, characterised by difficulty of prediction and mitigation.
Familiarity	EA5	EA5: Can extend beyond previous experiences by applying principles-based approaches.

Summary

- Washington Accord under IEA deals with engineering education | **BAETE**
- All engineering program must have achieved graduate attributes
  - Knowledge profile
  - Complex engineering problem
  - Complex engineering activities
- Complex engineering problems / activities → differentiate engineering from technologist / technician level programs
- Complex engineering problems / activities must be addressed through courses, projects, thesis, industrial training etc.

Thank you very much

Essentials of OBE Based Curriculum Design as per WA

A. S. M. A. Haseeb
Nanomaterials ad Ceramic Engineering Dept., BUET, Dhaka

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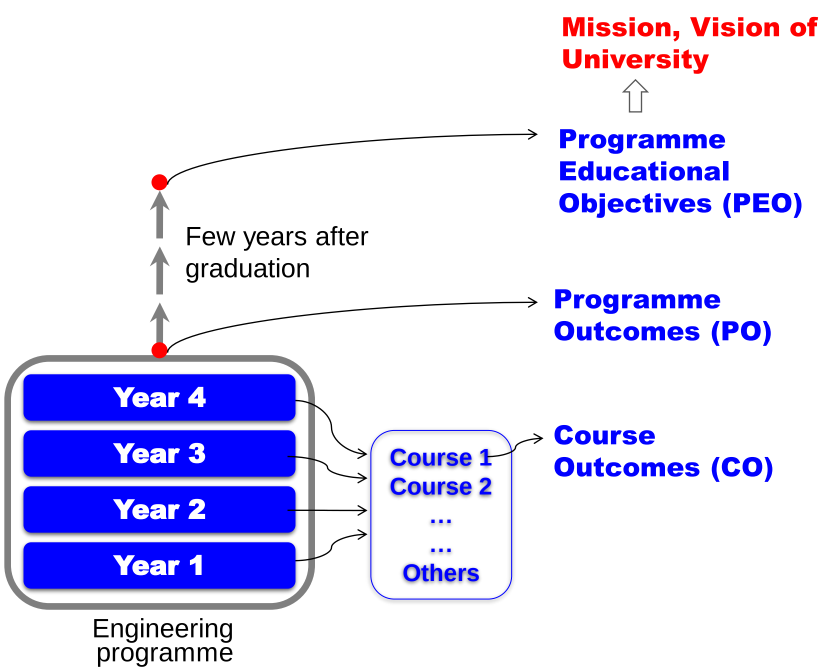

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Programme Educational Objectives (PEO)
Program educational objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve ***(3-5 years after graduation)***

Programme Outcomes (PO)
Program outcomes are narrower statements that describe what students are expected to know and be able to do by the ***time of graduation***. These relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the program.

Course Outcomes (CO)
Course outcomes are even narrower statements that describe what students are expected to know and be able to do at the ***end of the course***

3

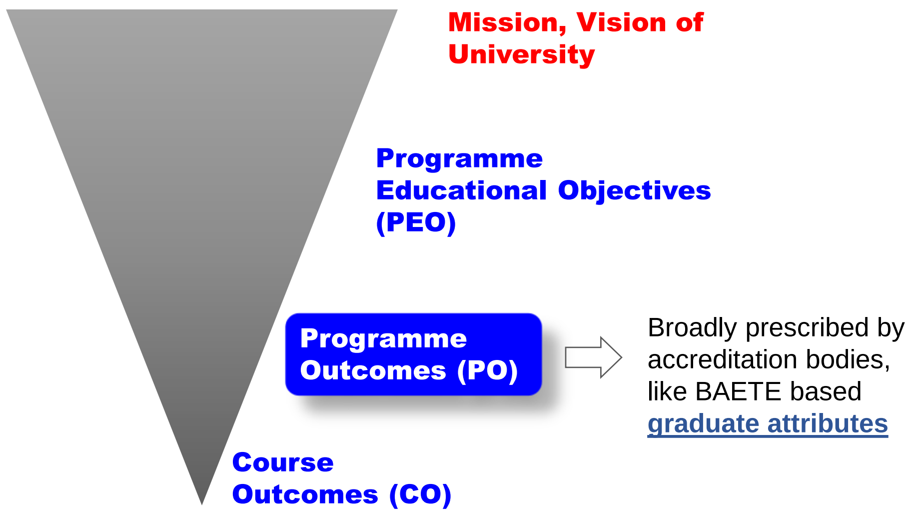
Terminology

Programme Educational Objectives (PEO)
Programme Objectives

Programme Outcomes (PO)
Student Outcomes
Programme Learning Outcomes

Course Outcomes (CO)
Learning Outcomes

4



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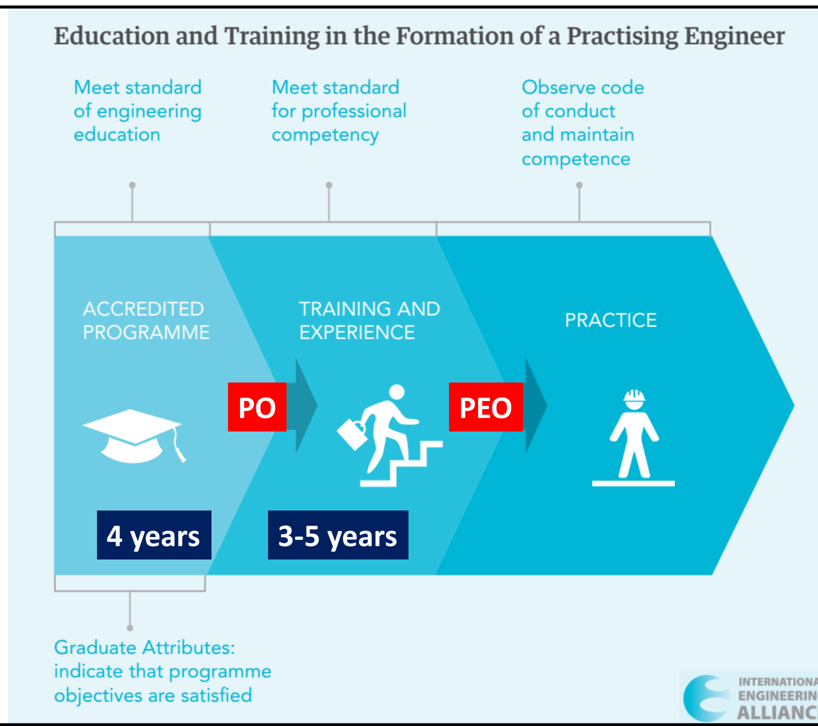
…**externally accredited** programme of four or five years …

…followed by a period of supervised training while gaining experience in engineering practice.



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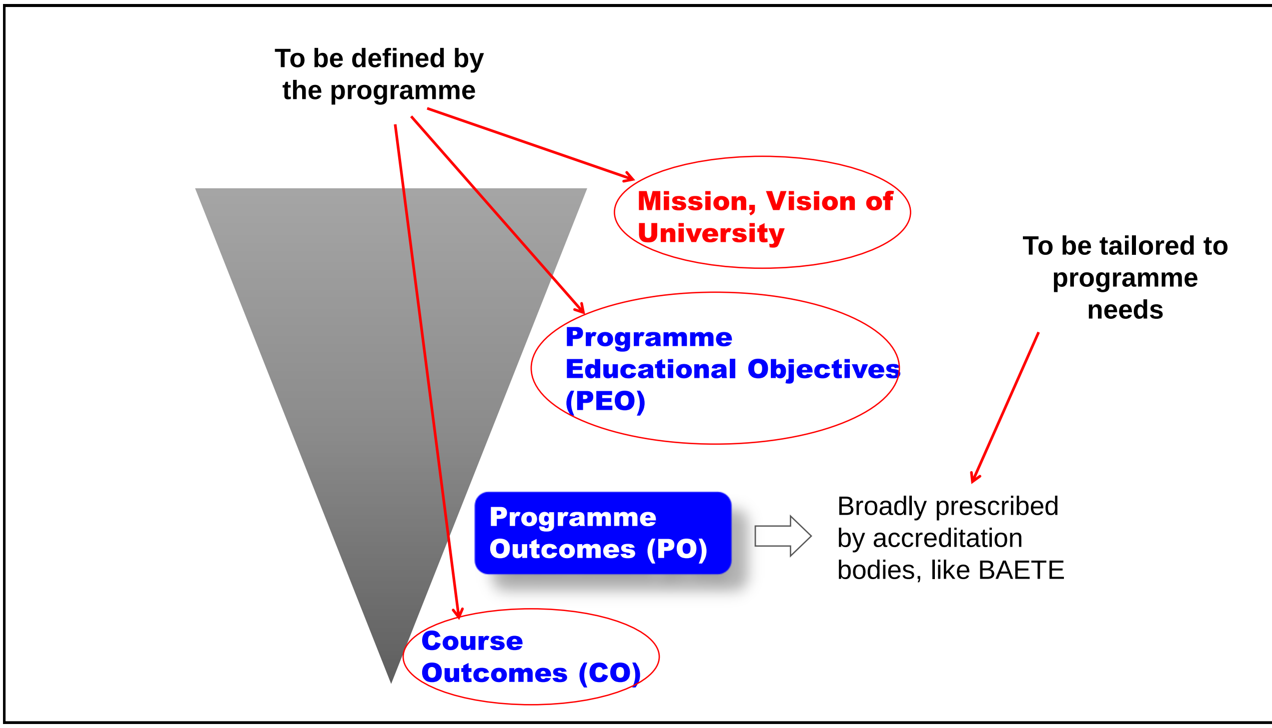

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BAETE specifically requires that students acquire the following graduate attributes:

PROGRAM OUTCOMES (PO)

a) Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in K1 to K4 respectively to the solution of complex engineering problems.

b) Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (K1 to K4)

c) 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. (K5)

d) Conduct investigations of complex problems using research-based knowledge (K8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

e) 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. (K6)

8

PROGRAM OUTCOMES (PO) contd…

f) 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. (K7)

g) Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts. (K7)

h) Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (K7)

i) Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.

j) 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.

k) Demonstrate knowledge and understanding of engineering 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.

l) Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Summary

- Institutions and programs define → their mission and objectives to meet the needs of their constituencies/stakeholders
- Emphasis on outcomes and preparation for professional practice
- Programs must demonstrate → how outcomes and educational objectives are being met
- Practice of continuous improvement
- Input of constituencies / stakeholders
- Student, faculty, facilities, institutional support, and financial resource issues linked to program objectives

Outcome Based Education: Basics

A. S. M. A. Haseeb
Nanomaterials ad Ceramic Engineering Dept., BUET, Dhaka

1

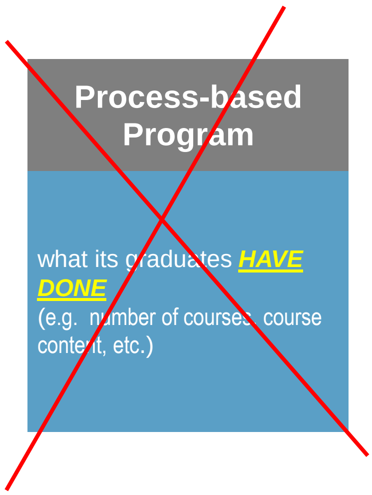
Washington Accord of IEA adopted

Outcome Based Education (OBE)

to ensure quality of engineering education

2

What is learned rather than what is taught



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“If the students have not learned then the teacher has not taught”

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William G. Spady, 1994

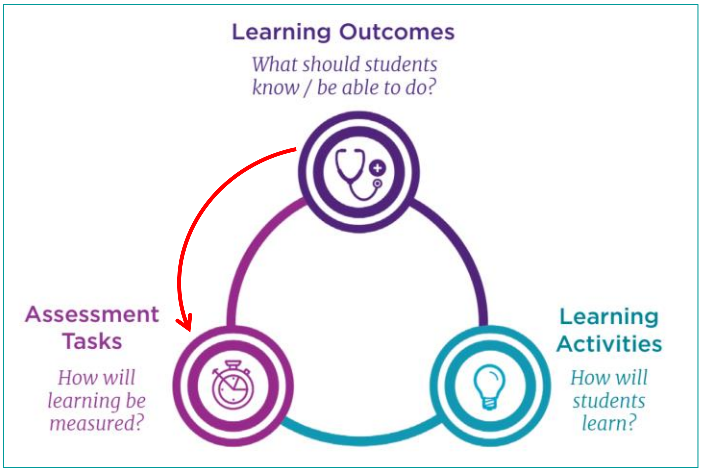
- Outcome-Based Education (OBE): a means to ensure **quality** in the American school system
- Eventually, OBE was extended to higher education system
- *'OBE means focusing and organizing an institute's entire programmes and instructional efforts around clearly defined outcomes we want all students to demonstrate when they leave the institute'*
- OBE is a system of education giving priority to ends, purposes, accomplishments and results.

At the heart of OBE is

Constructive Alignment

Constructive Alignment is based on

Constructivism	Alignment
learners construct or create meaning out of **learning activities** and what they learn (Cognitive psychology and Constructivist theory)	a curriculum **design** concept that emphasizes importance of **defining** and **achieving** intended learning **outcomes**



There should be logical alignment between all three elements.

(The Univ. of Queensland, Adapted from Biggs, 2003)

- Courses become congruent and coherent in an explicit way: **good fit and flow between learning outcomes, learning activities and assessment**
- Support students in developing as much meaning and learning as possible from a **well designed, coherent, and aligned course**.

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Benefits constructive alignment

- Leads students to success both in assessments and to achievement of learning outcomes
- Helps students to feel confident in their work, their engagement and their study
- Ensures that "learner cannot escape without learning what is intended" (Biggs, 2003).

(The Univ. of Queensland)

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Guide for Constructive Alignment

1. Write **course outcomes (COs)** that are:	a. relevant b. concrete and achievable, and c. simple and active – with **one verb in each**
2. Create **learning activities** that require students to engage each verb in the COs	a. practical COs require practical activities (ability to do..x,y,z) b. COs about facts require activities recalling facts (ability to name/recall facts x,y,z) c. COs about integration/application of knowledge in practice require activities that involve application of knowledge in practice (ability to apply theory in practice) d. COs about reasoning require opportunities to practice reasoning, etc. (ability to problem-solve/analyse/diagnose…etc)
3. Design **assessment** tasks and types that:	a. match, mirror or emulate the COs and their **associated verbs** b. can be assessed using rubrics for grading performance criteria and standards (Biggs, 2014, p. 8).

https://pressbooks.pub/flexforward/chapter/constructive-alignment/

9

How to analyse a learning outcome

Analyse learning outcome in order to choose assessment method:

1. Identify the skills or actions you want students to demonstrate. Is it a cognitive skill or a professional or practical skill?

2. Determine level of thinking you want students to demonstrate. Are they lower order thinking skills or higher order thinking skills?

The level of thinking is related to the verb in the learning outcome indicating what skill the student is expected to achieve.

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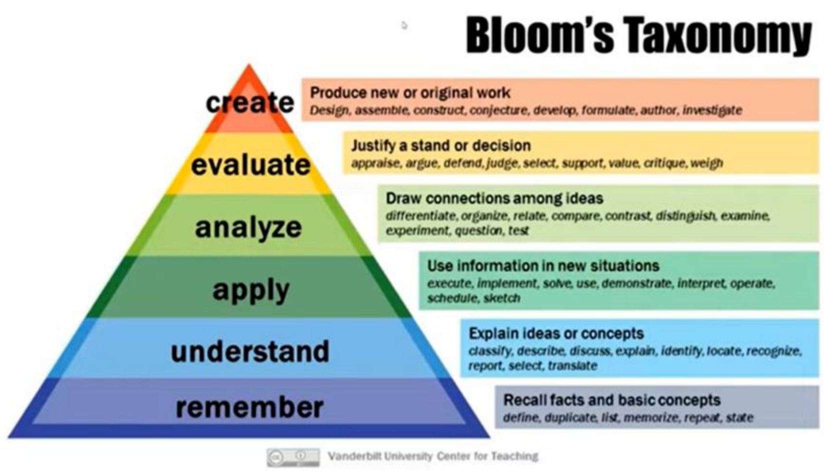
Levels of cognitive skills



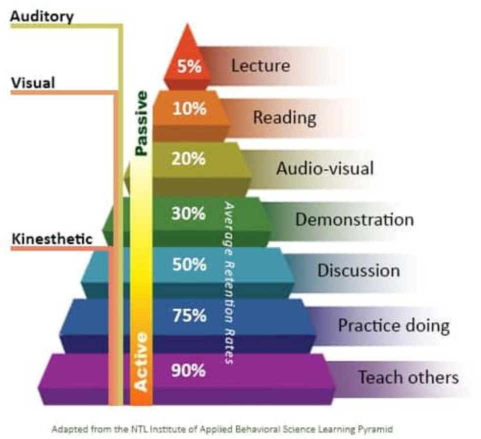
https://federation.edu.au/staff/learning-and-teaching/curriculum-quality/tertiary-education-standards/constructive-alignment

Constructive alignment approach recognizes

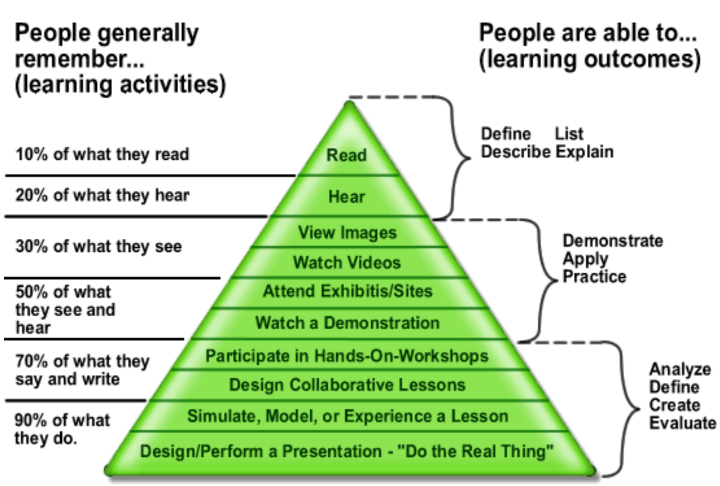
"knowledge is constructed by the activities of the learner" (Biggs, 2014, p. 9) rather than being directly transferable from teacher to student.

"Learning takes place through the active behavior of the student: it is what *he* does that he learns, not what the teacher does." (Tyler, 1949)

Learning pyramid



Different degrees of retention induced from various type of learning



Learning activities must match the intended learning outcomes

Student Centered Learning

- Problem Based Learning
- Case Study
- Project-based learning
- Flipped Classroom
- Cooperative learning
- Experiential learning
- Peer-to-peer Instruction
- Scenario based learning

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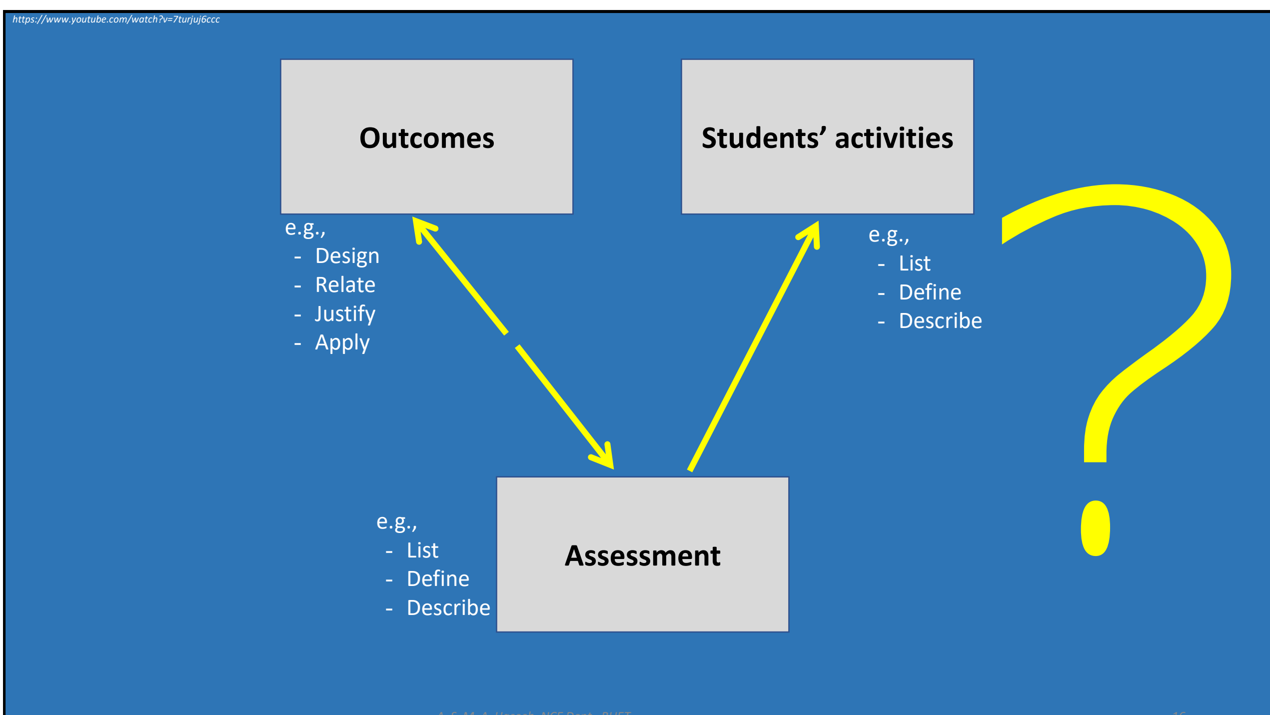

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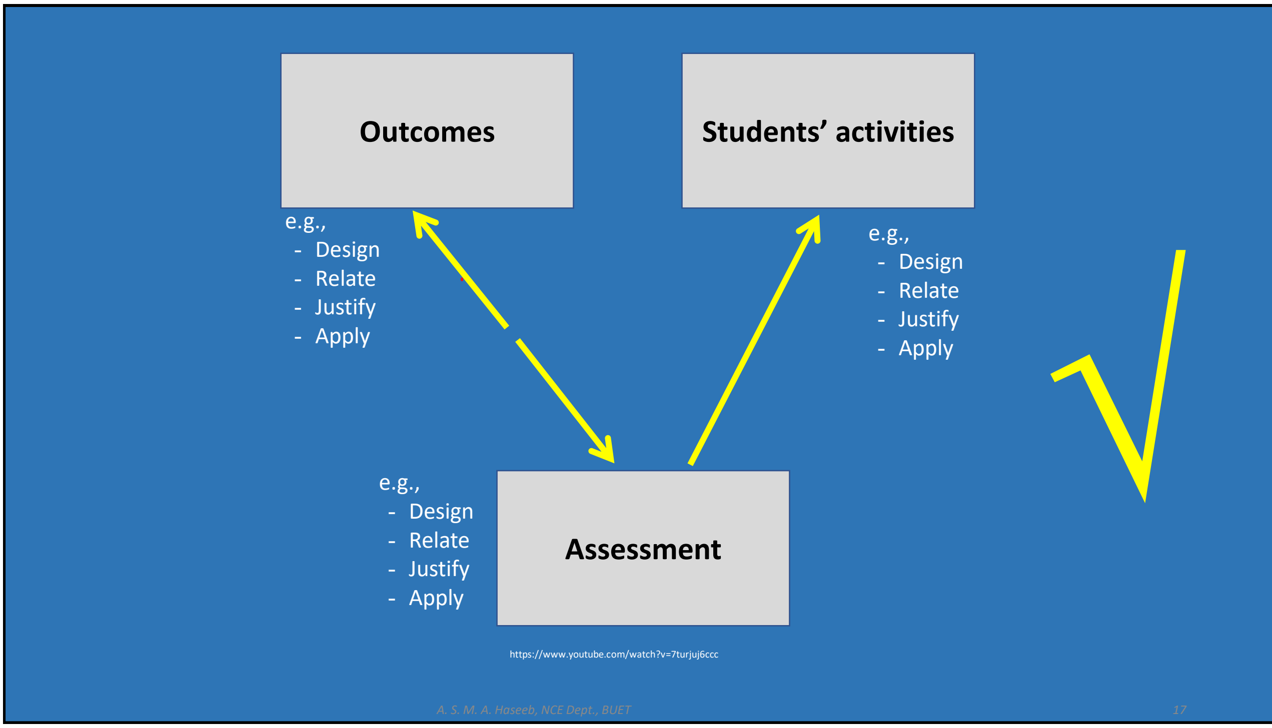

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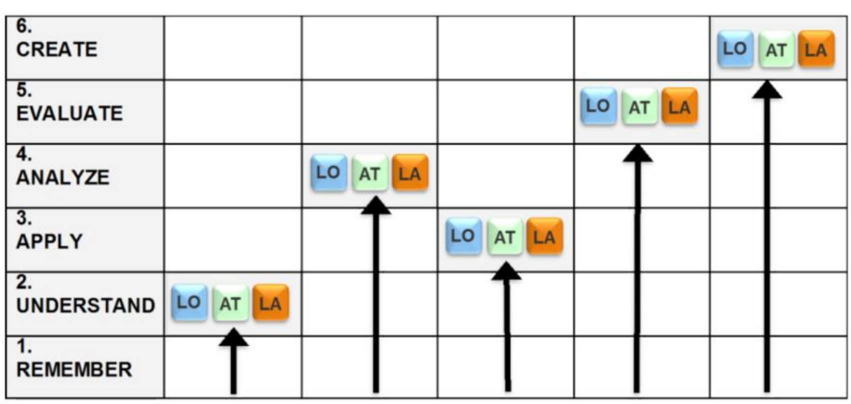
https://ethz.ch/en/the-eth-zurich/education/educational-development/unterrichtsgestaltung/constructive-alignment.html

LO: Learning Outcomes / AT: Assessment Tasks / LA: Learning Activities



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https://onderwijstips.ugent.be/en/tips/opleidingsonderdeel-samenstellen/

Another example of misalignment

Outcome	students are able to run a marathon
Teaching activities	formal lectures comprising an overview of various running disciplines
Exam	multiple choice questions about Olympic marathon winners

- **Surely students will focus on memorizing names of marathon winners rather than on training for a marathon**
- **The course then defeats its purpose !**

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Teaching Teaching & Understanding Understanding

https://www.youtube.com/watch?v=7turjuj6ccc

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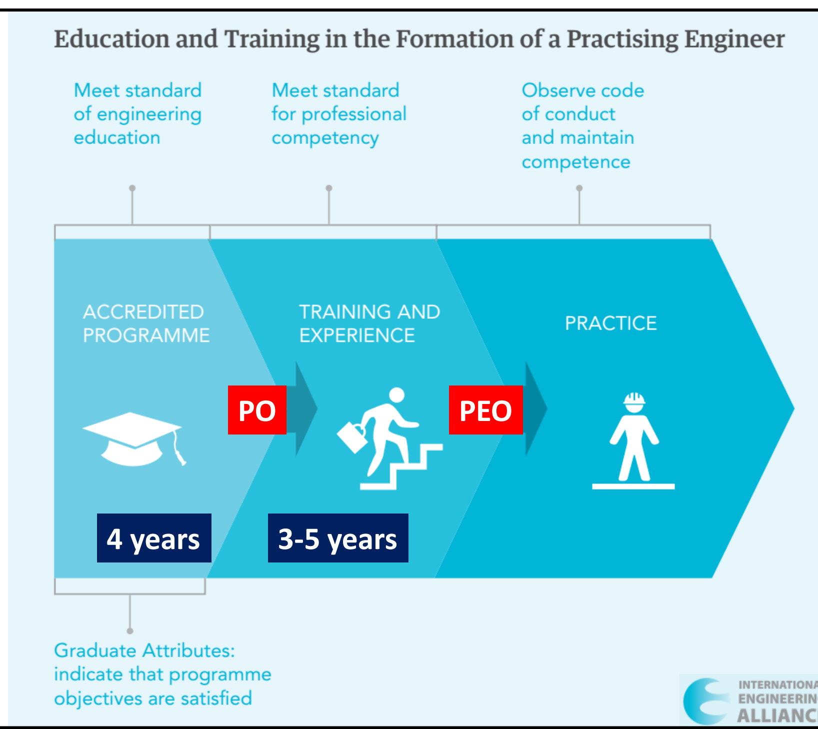
*“Outcome-based education means starting with a clear picture of what is important for **students to be able to do**, then organising the curriculum, instruction, and assessment to **make sure** that this learning ultimately happens.”* (Spady, 1994)

...**externally accredited** programme of four or five years ...

...followed by a period of supervised training while gaining experience in engineering practice.



Summary

Implementation of Outcome Based Education

A. S. M. A. Haseeb
Nanomaterials ad Ceramic Engineering Dept., BUET, Dhaka

Implementation of OBE

- Formulate PEO, PO, CO
- Prepare CO-PO matrix → make sure that each PO is covered in at least a few courses
- Questions should be designed to address all CO
- Analyse the course results in terms of CO → set indicator for achievement, then check if the target is achieved
- End of semester → analyze CO, PO achievement for each cohort or batch, and each student
- End of graduation semester → analyze all CO, PO achievements for each cohort or batch, and each student
- Achievement of PEO → a few years after graduation

EVERYTHING MUST BE DOCUMENTED → For independent verification

Programme Educational Objectives (PEO)

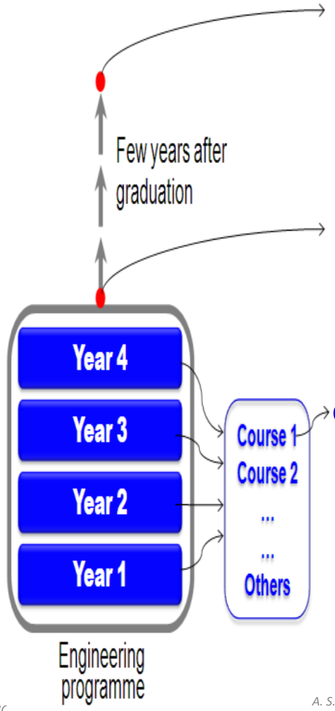
Broad statements that describe career and professional accomplishments that program is preparing graduates to achieve

Programme Outcomes (PO)

Narrower statements that describe what students are expected to **know** and be able to **do** by the ***time of graduation*** → relate to skills, knowledge, and behaviors that students acquire in their matriculation

Course Outcomes (CO)

Even narrower statements that describe what students are expected to **know** and be able to **do** at the ***end of the course***



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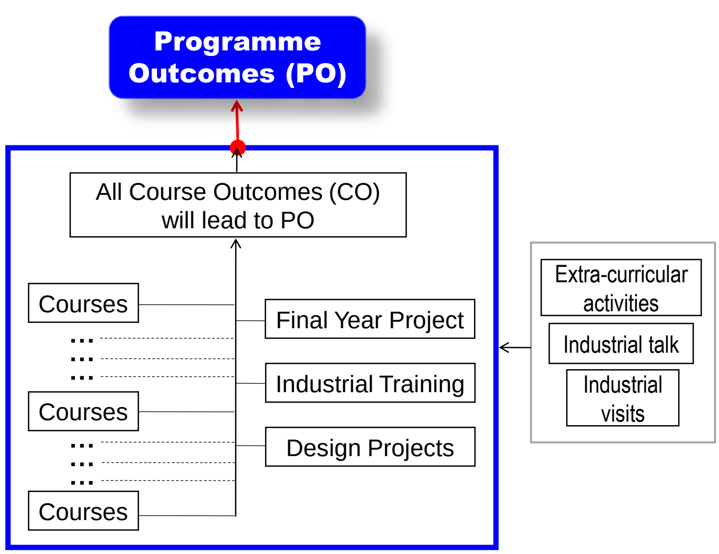

Engineering programme

4

So development of
academic curriculum
with
well-defined and measurable CO, PO
is crucial
to the implementation of OBE

⇩

- **Design each individual courses following the requirements of OBE**
- **Very important component → Course Outcome (CO)**

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Formulation of Course Outcomes (CO)

- Written using action words → what students will be able to do and/or know at the end of the course
- CO should reflect appropriate level of difficulties → befitting an engineering programme
- Modern learning theories are used → Blooms taxonomy
- Provide learning activities which will help the student to reach these outcomes → Active learning (AL), Cooperative Learning (CL), Project/Problem Based Learning (PBL) etc
- Each CO must contribute to PO
- CO-PO matrix for the whole programme→ make sure that all POs are **adequately** addressed

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Difference among Engineers, Technologists and Technicians

In term of Problem Analysis ….

Engineers (Washington Accord)	**Technologists** (Sydney Accord)	**Technicians** (Dublin Accord)
Identify, formulate, research literature and solve ***complex*** engineering problems reaching substantiated conclusions using *first principles of mathematics and engineering sciences*	Identify, formulate, research literature and solve ***broadly-defined*** engineering problems reaching substantiated conclusions using *analytical tools appropriate to their discipline or area of specialisation*	Identify and solve ***well-defined*** engineering problems reaching substantiated conclusions using *codified methods of analysis specific to their field of activity*

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Difference among Engineers, Technologists and Technicians…

Engineers Solve **Complex Problems**	***Technologists Solve*** **Broadly-defined Problems**	***Technicians Solve*** **Well-defined Problems**
Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	Can be solved by well-proven analysis techniques	Can be solved in standardized ways

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Bloom’s Taxonomy

- Developed by Dr. Benjamin S Bloom, 1956 → Taxonomy of Educational Objectives
- Focus on 'mastery' of subjects
- Promotion of higher forms of thinking, rather than fact transfer and information recall
- Covers all human aspects – Cognitive Domain, Affective Domain and Psychomotor Domain

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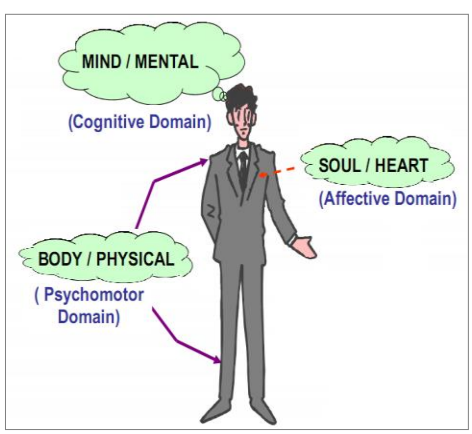
1. **Cognitive domain:** intellectual capability, knowledge → '*think*'
2. **Affective domain:** feelings emotions and behaviour, i.e., attitude, belief → *'feel'*
3. **Psychomotor domain:** manual and physical skills i.e., skills → *'do*'



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Levels of Cognitive, Affective and Psychomotor domains

Cognitive	Affective	Psychomotor
knowledge	**attitude**	**skills**
1. Recall data	1. Receive (awareness)	1. Imitation (copy)
2. Understand	2. Respond (react)	2. Manipulation (follow instructions)
3. Apply (use)	3. Value (understand and act)	3. Develop Precision
4. Analyse (structure/elements)	4. Organise personal value system	4. Articulation (combine, integrate related skills)
5. Synthesize (create/build)	5. Internalize value system (adopt behaviour)	5. Naturalization (automate, become expert)
6. Evaluate (assess, judge in relational terms)		

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Cognitive domain

Intellect - Knowledge - Thinking Ability

LEVEL	ORIGINAL *(Blooms 1956)*	REVISED *(Anderson 2001)*
1	KNOWLEDGE	REMEMBERING
2	COMPREHENSION	UNDERSTANDING
3	APPLICATION	APPLYING
4	ANALYSIS	ANALYSING
5	SYNTHESIS	EVALUATING
6	EVALUATION	CREATING / DESIGNING

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COGNITIVE DOMAIN				
level	category or 'level'	behaviour descriptions	examples of activity to be trained, or demonstration and evidence to be measured	'key words' (verbs which describe the activity to be trained or measured at each level)
1	Knowledge (REMEMBERING)	recall or recognise information	multiple-choice test, recount facts or statistics, recall a process, rules, definitions; quote	arrange, define, describe, label, list, memorise, recognise, relate, reproduce,
			law or procedure	select, state
2	Comprehension (UNDERSTANDING)	understand meaning, re-state data in one's own words, interpret, extrapolate, translate	explain or interpret meaning from a given scenario or statement, suggest treatment, reaction or solution to given problem, create examples or metaphors	explain, reiterate, reword, critique, classify, summarise, illustrate, translate, review, report, discuss, re-write, estimate, interpret, theorise, paraphrase, reference, example

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3	Application (APPLYING)	use or apply knowledge, put theory into practice, use knowledge in response to real circumstances	put a theory into practical effect, demonstrate, solve a problem, manage an activity	use, apply, discover, manage, execute, solve, produce, implement, construct, change, prepare, conduct, perform, react, respond, role-play
4	Analysis (ANALYSING)	interpret elements, organizational principles, structure, construction, internal relationships; quality, reliability of individual components	identify constituent parts and functions of a process or concept, or de-construct a methodology or process, making qualitative assessment of elements, relationships, values and effects; measure	analyse, break down, catalogue, compare, quantify, measure, test, examine, experiment, relate, graph, diagram, plot, extrapolate, value, divide
			requirements or needs	
5 (6)	Synthesis (create/build) (CREATING / DESIGNING)	develop new unique structures, systems, models, approaches, ideas; creative thinking, operations	develop plans or procedures, design solutions, integrate methods, resources, ideas, parts; create teams or new approaches, write protocols or contingencies	develop, plan, build, create, design, organise, revise, formulate, propose, establish, assemble, integrate, re-arrange, modify

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6 (5)	**Evaluation** (EVALUATING)	assess effectiveness of whole concepts, in relation to values, outputs, efficacy, viability; critical thinking, strategic comparison and review; judgement relating to external criteria	review strategic options or plans in terms of efficacy, return on investment or cost-effectiveness, practicability; assess sustainability; perform a SWOT analysis in relation to alternatives; produce a financial justification for a proposition or venture, calculate the effects of a plan or strategy; perform a detailed and costed risk analysis with recommendations and justifications	review, justify, assess, present a case for, defend, report on, investigate, direct, appraise, argue, project-manage

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Example of Cognitive Levels

LEVEL	DESCRIPTION	EXAMPLE 1 (Cartoon Character)
1	REMEMBERING	List down (as many as you wish) cartoon characters that you watch on TV
2	UNDERSTANDING	Select one cartoon charater that you like most and describe its character. Use sketch if necessary
3	APPLYING	Explain how these characters can help you in real life
4	ANALYSING	Choose three cartoon character that you like most and study the similarities, differences, strengths and weakness
5	EVALUATING	Out of three above, which one (in your opinion) is the best character and explain the reasons behind your selection
6	CREATING / DESIGNING	Based on the cartoon characters that you have watched, create a new cartoon character (sketch) and describe its features and main characters

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Example of Cognitive Levels

LEVEL	DESCRIPTION	EXAMPLE 2 (Shipyard Location and Layout)
1	REMEMBERING	List down five characteristics for selecting shipyard location / Three characteristics of a good shipyard layout
2	UNDERSTANDING	Briefly explain one of the characteristics listed above. Use sketch if necessary
3	APPLYING	Based on the characteristics of shipyard location above, prepare a survey work to be carried out on the selected location
4	ANALYSING	Based on the data collected from several potential locations, analyse the strength and weaknesses of each location.
5	EVALUATING	Based on the analysis above, make your judgment on which location to be selected
6	CREATING / DESIGNING	Based on the characteristics of a good shipyard layout, and the given piece of land (map), propose a suitable layout for a medium size steel ship.

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Action word for each Cognitive Levels

Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Define Identify List Name Recall Recognize Record Relate Repeat Underline	Choose Cite examples of Demonstrate use of Describe Determine Differentiate between Discriminate Discuss Explain Express Give in own words Identify Interpret Locate Pick Report Restate Review Recognize Select	Apply Demonstrate Dramatize Employ Generalize Illustrate Interpret Operate Operationalize Practice Relate Schedule Shop Use Utilize Initiate	Analyze Appraise Calculate Categorize Compare Conclude Contrast Correlate Criticize Deduce Debate Detect Determine Develop Diagram Differentiate Distinguish Draw conclusions Estimate Evaluate Examine Experiment	Arrange Assemble Collect Compose Construct Create Design Develop Formulate Manage Modify Organize Plan Prepare Produce Propose Predict Reconstruct Set-up Synthesize Systematize Devise	Appraise Assess Choose Compare Critique Estimate Evaluate Judge Measure Rate Revise Score Select Validate Value Test

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Typical Course info

Department of XXX Engineering
Faculty of Engineering
University of XXX

(1) Course Code: **XXX**
(2) Course Title: **Engineering Alloys**
(3) Course Type: **Departmental (Core Course)**
(4) Synopsis:
The course focuses upon the processing-structure-property relationships in metals. The course is designed to start with pure metals, examining the role of (i) deformation and (ii) temperature in governing the structure and properties. Later, complexity is added through (iii) chemical additions, i.e., alloying, and the course culminates with detailed discussions of important alloy systems, most notably, Fe-C.

(5) Pre-requisite (If any):
None

(6) References:
- Structure and Properties of Engineering Alloys, William F. Smith. McGraw-Hill International Editions
- Materials Sciences and Engineering, An Introduction William D. Callister, Jr. John Wiley & Sons, Inc. Hill
- Mechanical Metallurgy, George E Dieter, McGraw-Hill

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7. Course Outcomes

	Course outcomes (CO)	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	**Delivery**	**Assessment**
By the end of this course, students will be able to:														
1	Explain the fundamentals of dislocations and describe relationship between dislocation motion, work hardening and strengthening.	√		√									Classroom instruction, AL/ CL,	Examination/ quiz/ written assignment report
2	Correlate between microstructure, thermal processing conditions and properties of ferrous alloys.	√	√	√									Classroom instruction , Tutorial, AL/ CL, lab sessions	Examination/ quiz/ written assignment report, lab report
3	Select type of alloying additions, thermal processing conditions, etc. for ferrous alloys for specific applications.	√		√									Classroom instruction, case study and AL/CL	Examination/ quiz/ written assignment report
	Overall	√	√	√										

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Action words in CO and levels of Bloom's Taxonomy

	Course outcomes (CO)	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	Delivery	Assessment
By the end of this course, students will be able to:														
1	**Explain** the fundamentals of dislocations and describe relationship between dislocation motion, work hardening and strengthening.	√		√									Classroom instruction, AL/ CL,	Examination/ quiz/ written assignment report
2	**Correlate** between microstructure, thermal processing conditions and properties of ferrous alloys.	√	√	√									Classroom instruction , Tutorial, AL/ CL, lab sessions	Examination/ quiz/ written assignment report, lab report
3	**Select** type of alloying additions, thermal processing conditions, etc. for ferrous alloys for specific applications.	√		√									Classroom instruction, case study and AL/CL	Examination/ quiz/ written assignment report
	Overall	√	√	√										

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Action word for each Cognitive Levels

Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Define Identify List Name Recall Recognize Record Relate Repeat Underline	Choose Cite examples of Demonstrate use of Describe Determine Differentiate between Discriminate Discuss Explain Express Give in own words Identify Interpret Locate Pick Report Restate Review Recognize Select	Apply Demonstrate Dramatize Employ Generalize Illustrate Interpret Operate Operationalize Practice Relate Schedule Shop Use Utilize Initiate	Analyze Appraise Calculate Categorize Compare Conclude Contrast Correlate Criticize Deduce Debate Detect Determine Develop Diagram Differentiate Distinguish Draw conclusions Estimate Evaluate Examine Experiment	Arrange Assemble Collect Compose Construct Create Design Develop Formulate Manage Modify Organize Plan Prepare Produce Propose Predict Reconstruct Set-up Synthesize Systematize Devise	Appraise Assess Choose Compare Critique Estimate Evaluate Judge Measure Rate Revise Score Select Validate Value Test

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MAPPING OF
COURSE OUTCOME TO PROGRAMME OUTCOMES

COURSE CODE	COURSE TITLE	CREDIT	PROGRAMME LEARNING OUTCOMES (PO)										
			PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
KXEX1145	Basic Engineering Algebra	2	√				√	√					
KXEX2244	Ordinary Differential Equations	2	√				√	√					
KXEX2162	Economy and Finance for Engineers	2	√		√	√	√	√					
KXEX2166	Law and Engineer	2	√			√	√						
KXEX2165	Moral and Ethics in Engineering Profession	2	√		√	√	√	√					
KXEX2245	Vector Analysis	2	√							√	√		√

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BAETE specifically requires that students acquire the following graduate attributes:

PROGRAM OUTCOMES (PO)

a) Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in K1 to K4 respectively to the solution of complex engineering problems.

b) Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (K1 to K4)

c) 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. (K5)

d) Conduct investigations of complex problems using research-based knowledge (K8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

e) 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. (K6)

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PROGRAM OUTCOMES (PO) contd…

f) 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. (K7)

g) Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts. (K7)

h) Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (K7)

i) Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.

j) 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.

k) Demonstrate knowledge and understanding of engineering 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.

l) Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

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OBE Assessment Methods

Direct

- Exams, assignments, tests, quizzes
- Final year projects
- Laboratory

} Marks translated into achievement of outcome

Indirect

- Industrial training
- Exit surveys
- Course surveys

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Assessment Tools

- Exit surveys, Exit interviews (P)
- Alumni surveys and interviews (P)
- Employer surveys and interviews (P)
- Job offers, starting salaries (relative to national benchmark) (P)
- Admission to graduate schools (P)
- Performance in group and internship assignments (P,C)
- Assignments, report and tests (P,C)

- Student surveys, individual and focus group interviews (P,C)
- Peer-evaluations, self evaluations (P,C)
- Student portfolios (P,C)
- Behavioral observation (P,C)
- Written tests linked to learning objectives (C)
- Written project reports (C)
- Oral presentation, live or videotape (C)
- Research proposals, student-formulated problems (C)
- Classrooms assessment techniques (C)

P: Program C: Course

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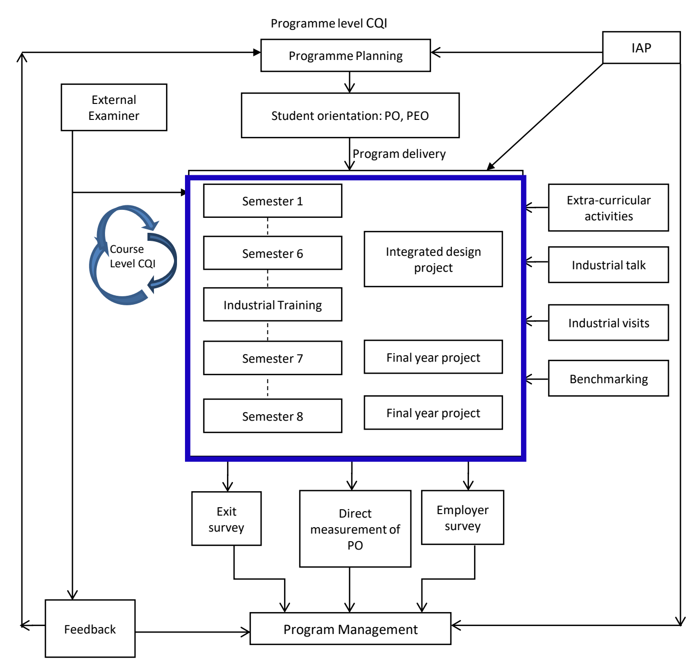

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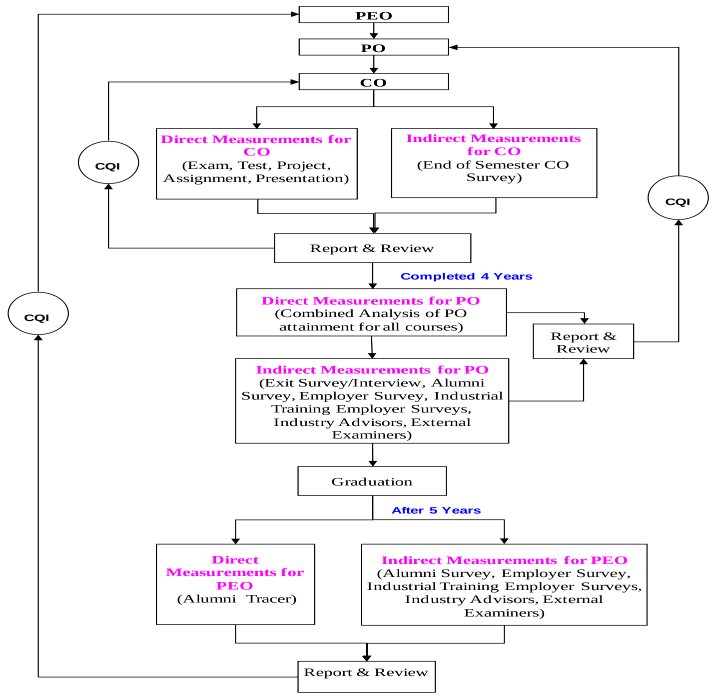

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Continuous Quality Improvement (CQI)

- Assessment and evaluation processes → provide critical information on the effectiveness of the design, delivery, and direction of an educational program - CQI
- Improvements → based on feedback from evaluations will close the system loop and the process will continue year after year.

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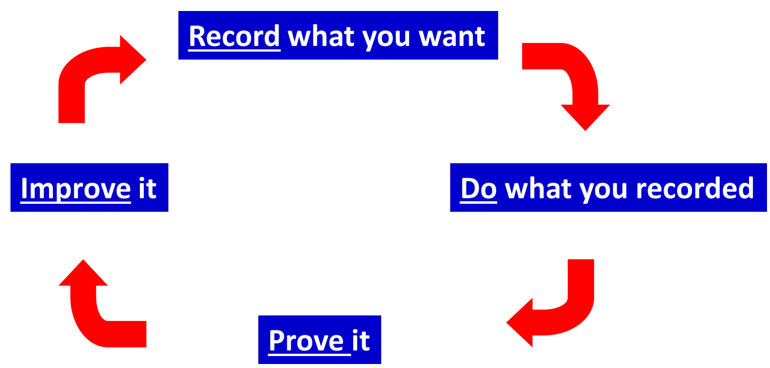
Continuous Quality Improvement (CQI)



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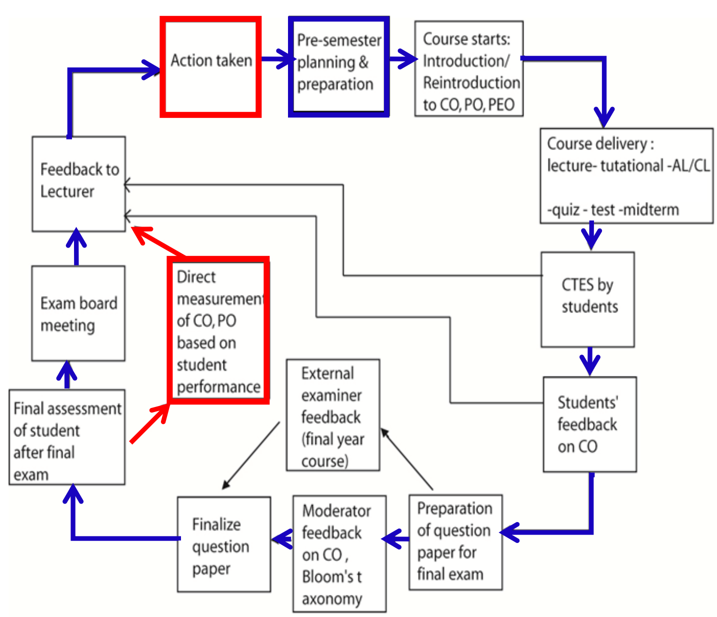

Process flow for CO and PO measurement and CQI at the course level

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Major Steps

1. Course design
2. Course delivery
3. Assessment
4. Measurement of achievement of CO
5. Analysis and plan for further improvement

1. Course design

- Not just copy from overseas Universities
- Feedback from stakeholders: Industry, employers, alumni, teachers, students

2. Course delivery

- Lectures alone are not considered adequate enough
- Student centered learning: Active Learning (AL) in the class, Cooperative Learning (CL), Problem Based Learning (PBL), Project Based Learning

3. Assessment

- Coverage and depth of CO
- All COs must be adequately covered
- Bloom's taxonomy is used to ensure that COs are covered at adequate depth
- Multiple assessment tools: quiz, test, presentation, PBL
- Assessment of questions for coverage of CO

4. Measurement of achievement of CO

- Two types: Direct and indirect measurement
- Direct measurement
  - e.g., from marks obtained (but different from marks obtained for grading)
  - set criteria for direct measurement, e.g.,
    if at least 70% of students achieve ≥ 50% marks related to say CO1,
    then CO1 for that course is considered to have been achieved
- Indirect measurement
  Student survey: check how far students perceive to have achieved CO

5. Analysis and plan for further improvement

- Analyze the achievements or otherwise of each CO
- Prepare a plan for further improvement for the next semester

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Assessment of question paper for quality assurance

	FACULTY OF ENGINEERING **UNIVERSITY OF MALAYA**
	ASSESSMENT OF FINAL EXAM QUESTIONS BASED ON THE COURSE OUTCOMES AND THE LEVEL OF BLOOM'S TAXONOMY

SESSION : 2012-2013 SEMESTER: 2

CODE / COURSE : YYY- 1xxx: Crystal Structure and Defects

MODERATOR : ....

SECTION 1: TO BE COMPLETED BY SUBJECT LECTURER				**SECTION 2: MODERATOR EVALUATION**	
No	Course Outcome (CO)	Exam Question(s) Addressing the CO	Level of Bloom's Taxonomy *	Question(s) addresses the CO satisfactorily (YES/NO/NA)	Comments
1	Explain crystal symmetry and crystal structure of different classes of materials	1a 1b 1c 1d 1e	C4 C2 C4 C3 C2		
2	Apply diffraction techniques to find out crystallographic information	2a 2b 2c	C2 C4 C5		
3	Distinguish among different crystal defects and their roles in determining materials properties	3 3 3	C4 C2 C6		

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Summary

- OBE → centered around the needs of the students and the stakeholders
- Objective and outcome driven → where every stated objective and outcomes *can be assessed and evaluated*
- Program Educational Objectives (PEO), Program Outcomes (PO), Course Outcomes (CO) and ***Performance Indicators***
- Requires non-traditional, innovative teaching approach → Active learning (AL), Cooperative Learning (CL), Project/Problem Based Learning (PBL) etc
- Continuous quality improvement (**CQI**)
- *Evidence based* → Independently verifiable documentation and record keeping

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