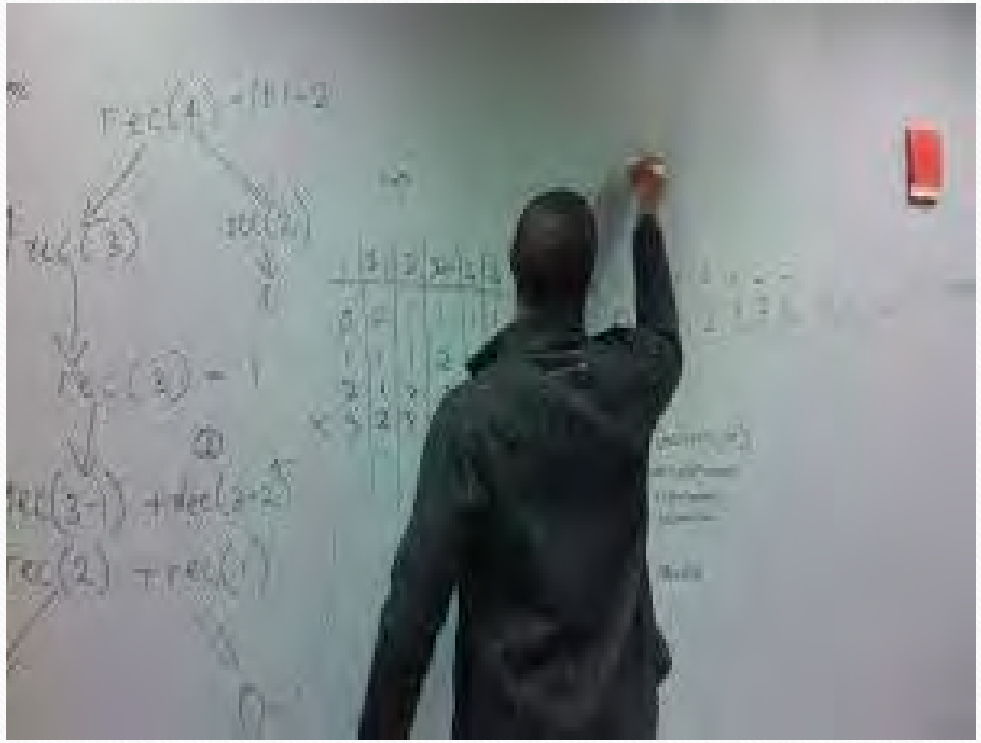
The Mathematics with Applications Workshop

Setting the framework for the workshop

Abel Nyamapfene

Mike Peters

Some advice from a practising engineer

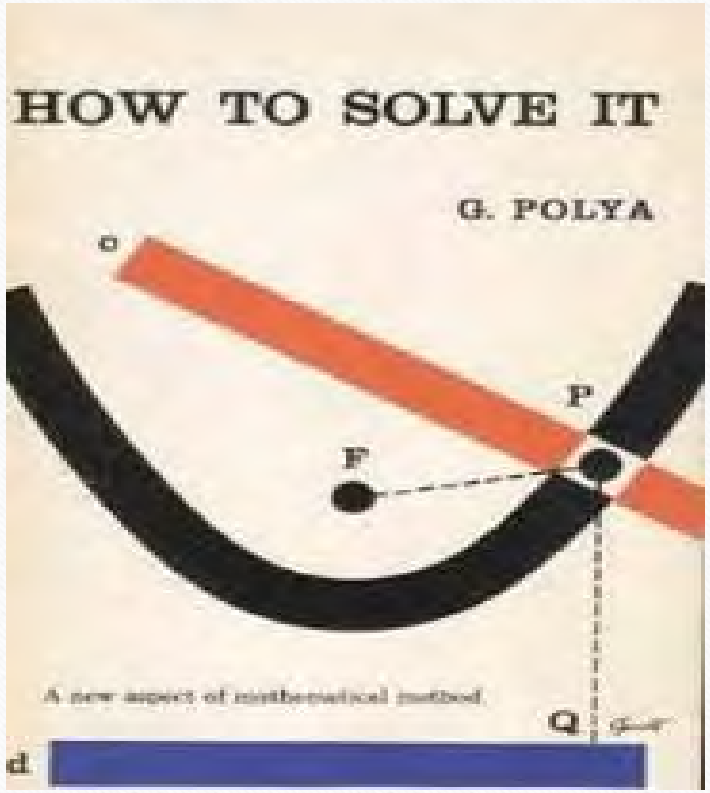


Engineers are often math enthusiasts who got bored with the abstract.

Even though number crunching is significant to engineers' work, **math is no more than a convenient means to arrive at a physical end.**

Will Charpentier, *What Math Skills Are Needed to Become an Engineer?* Houston Chronicle

Teaching Mathematics – a view from 1945



A teacher of mathematics has a great opportunity. If he fills his allotted time with drilling his students in routine operations, he kills their interest, hampers their intellectual development, and misuses his opportunity.

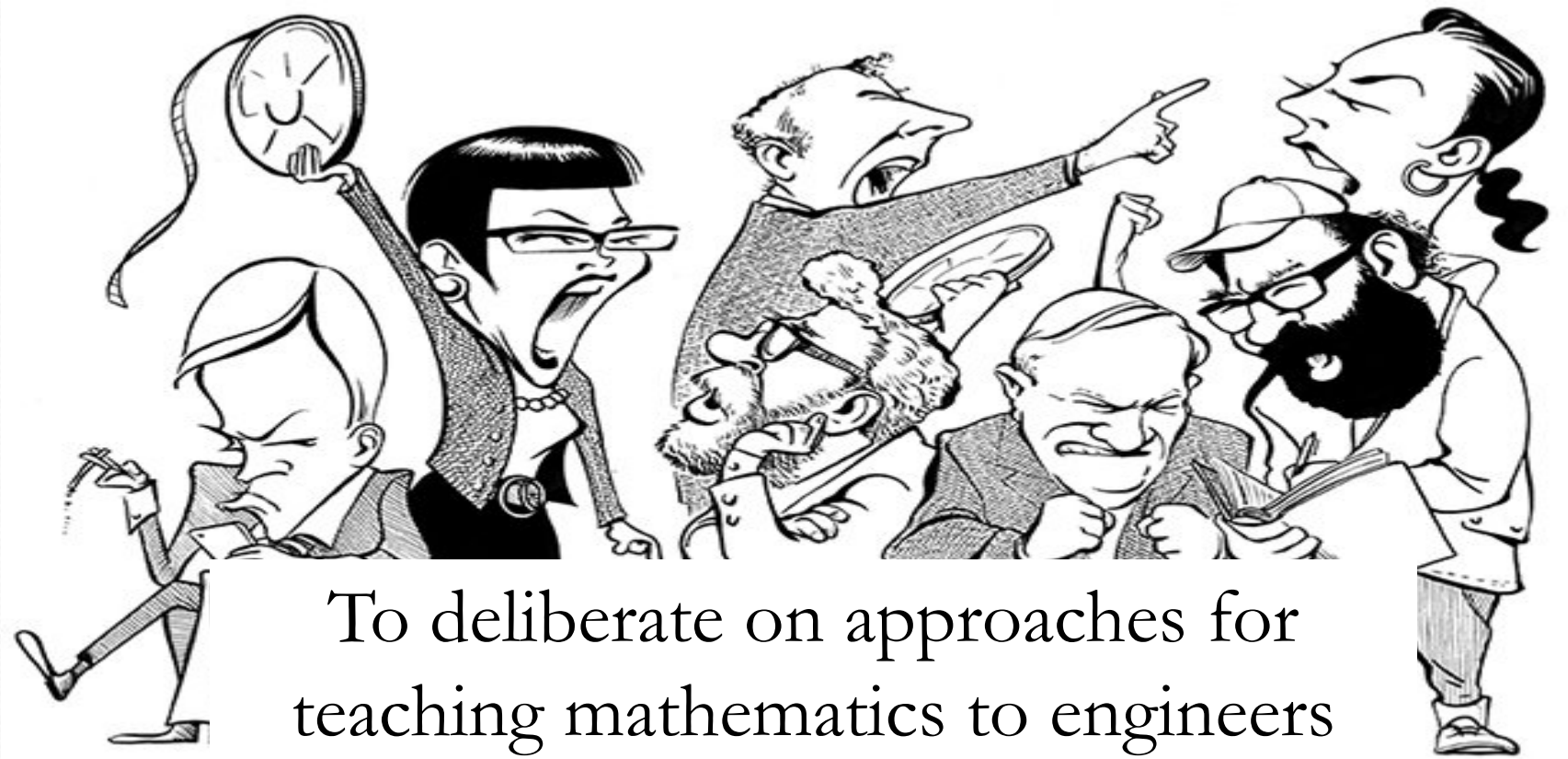
But **if he challenges the curiosity of his students** by setting them problems proportionate to their knowledge and helps them to solve their problems with stimulating questions, he may give them a taste for, and some independent means of, independent thinking. **[George Polya, 1945]**

A recent definition for mathematical competence

Mathematical competence is the ability to *understand, judge, do, and use mathematics* in a variety of intra- and extra-mathematical *contexts and situations* in which mathematics plays or could play a role

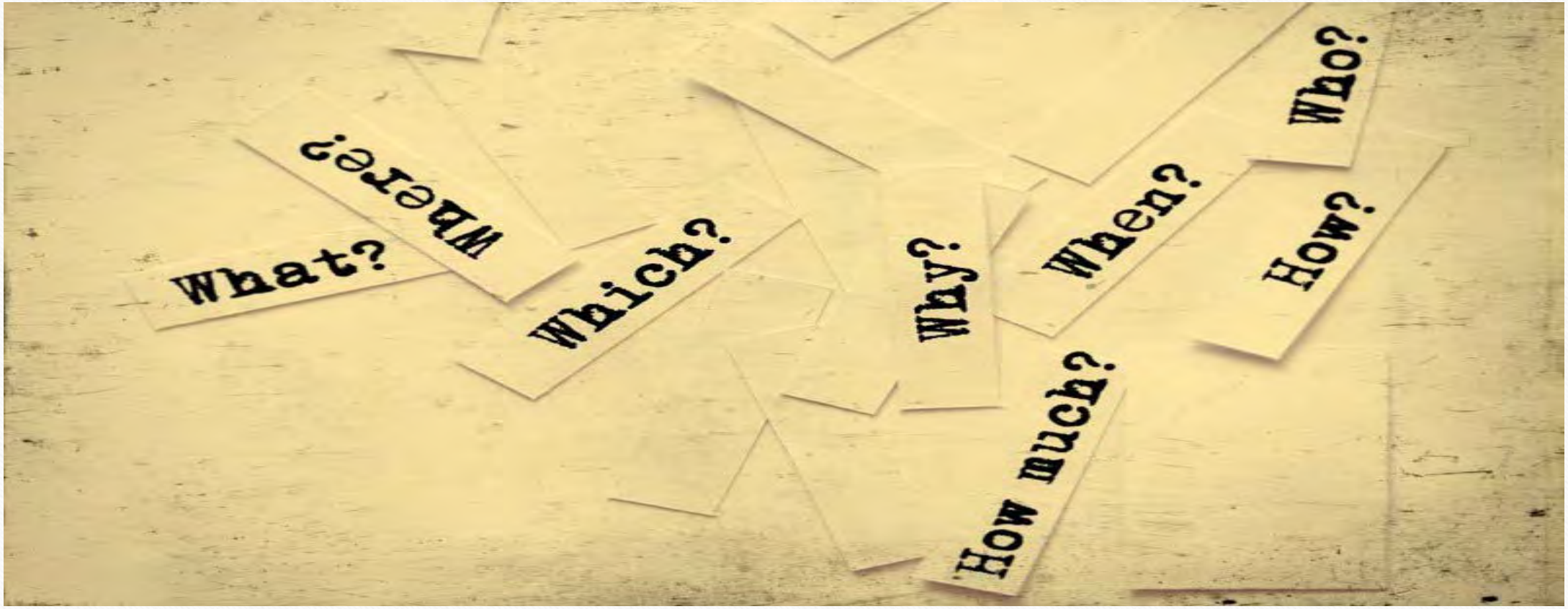
[Mathematics Working Group Report, 2013]

Our goal in this workshop:



To deliberate on approaches for teaching mathematics to engineers

So what sort of Guiding **Question(s)** should we be asking ourselves in order to guide our discussions and activities in this workshop?



Guiding Research Question:

What do we need to do to ensure that our provision of undergraduate engineering mathematics meets the knowledge and skills requirements for the 21st century?

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What do we need to do to ensure that our provision of undergraduate engineering mathematics meets the knowledge and skills requirements for the 21st century?

- What are the engineering mathematics knowledge and skills that South African engineers need for the 21st century?
- What is the current state of South African undergraduate engineering mathematics with regard to entry-level student attributes, university level curriculum and delivery, and current and expected future industry requirements?
- What do we need to do to enhance South Africa's provision of undergraduate engineering mathematics to ensure that it meets the knowledge and skills requirements for the 21st century?

Of course, we are not starting this investigation from scratch.

From the SEFI definition, what sort of skills and knowledge do we think we need to master if we are to address the guiding questions that we have formulated?

"Mathematical competence is the ability to *understand, judge, do, and use mathematics* in a variety of intra- and extra-mathematical *contexts and situations* in which mathematics plays or could play a role."

On successfully completing the workshop, you will be able to:

On successfully completing the workshop, we will be able to:

- **Implement problem based learning (PBL) in own teaching in engineering mathematics** with the intended objective of enabling students to recognise the connections between mathematics and engineering, and to use mathematics, individually, and as part of a team, to model and analyse engineering systems with a view to developing appropriate engineering solutions
- **Integrate mathematical modelling and analysis techniques into own teaching in engineering mathematics** with the intended objective of enabling students to develop and use mathematical frameworks to model and analyse real-world engineering systems
- **Integrate appropriate computer algebra systems, e.g. Matlab and Excel, into own teaching** in engineering mathematics with the intended objective of enabling students to use mathematical modelling and analysis techniques to efficiently solve and evaluate the performance of engineering systems

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Implementing Problem Based Learning within Engineering Mathematics

Mike Peters

Proposed Agenda

Why Engineering Education has to change
Homo practicus.
Engineering Habits of Mind.
Why PBL in Engineering mathematics.
Designing a ‘fit for purpose’ programme/module
Developing resources.

Aston model
UCL model


I have taught Snoopy to whistle
I can't hear him whistle
I said I had taught him, not that he had learned

Pathway to Modern Industrialisation

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Discussion 1

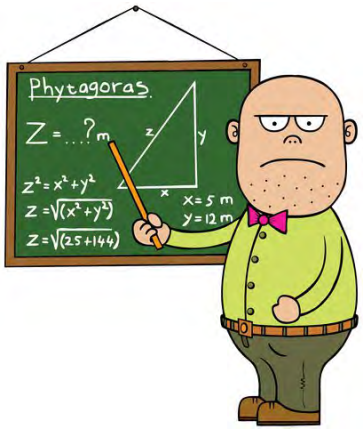
- Industrialisation in South Africa
- Expected outcomes of SA engineering programmes

Discussion 2

- How should teaching/learning be designed to promote autonomous, independent, investigative learning?

Reading, ‘riting and ‘rithmetic were the order of the day.

Teacher ‘sage on the stage’



Teacher dictates what, how and when

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Discussion 3

- What are engineers?
- What is engineering?

Homo practicus new or evolved species?

Engineers are thinkers

Engineers are investigators

Engineers are collaborators

Engineers are leaders

Engineers are creative problem solvers

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Discussion 4

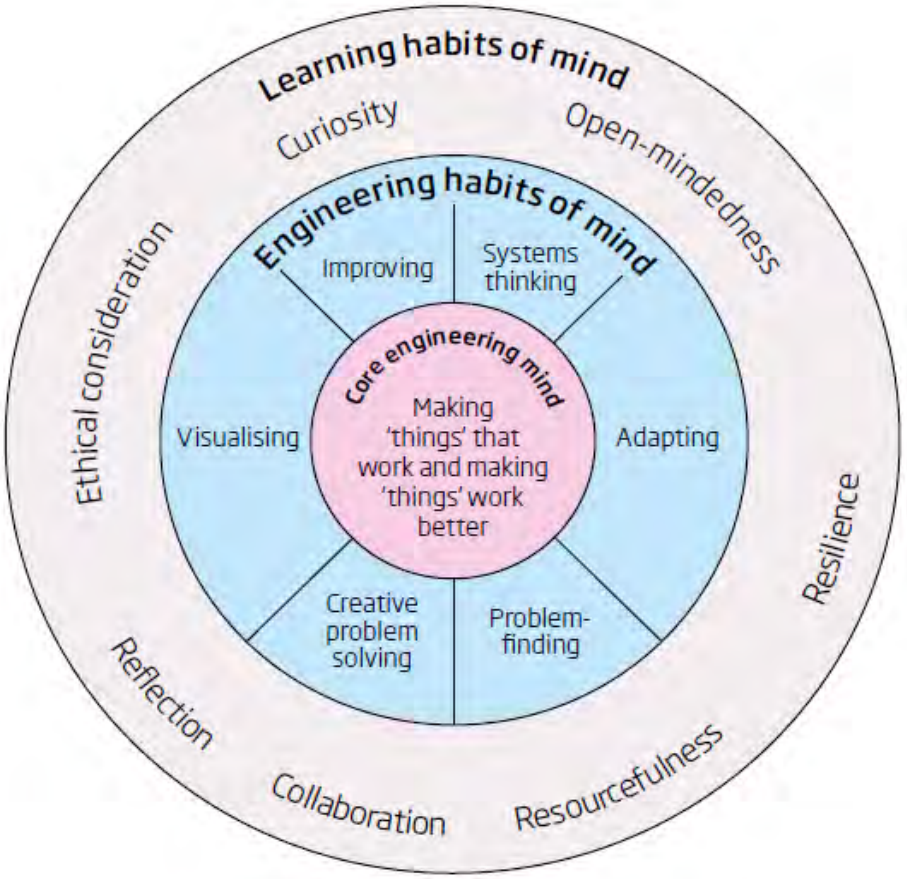
- What does South Africa require from their graduate engineers?
- What types of challenges do South African engineers face?

Seeds of Engineering

‘Young children are natural born engineers. As they engage with the world around them they are constantly seeking to understand the property of materials. A tower of bricks stands up for a few moments before toppling over and causes a surge of pleasure in the young mind. When the cardboard structure they have made is strong enough to bear the weight of other toys and become a medieval castle, there is the thrill of persistent and successful experimentation. Young children exhibit EHoM in the raw. They are prototype engineers or, if you like, ‘homo practicus’.’

(Lucas, Hanson and Glaxton 2014)

What are the ‘Engineering Habits of Mind (EHoM)?



What should learning be?

"…learning should involve many activities; memorising where necessary, but also relating new information to old, linking theoretical ideas or academic knowledge to personal experience wherever possible, adopting a critical stance to other peoples' ideas, and evaluating evidence with caution".

Entwhistle (1981, 4)

Seeds of Education – up to age 14 years

'We are of opinion that the curriculum of the primary school is to be thought of in terms of activity and experience, rather than of knowledge to be acquired and facts to be stored'

(Hadow 1931:139).

All courses 'should afford adequate practice in methods of individual and group work'

(Hadow 1931:144)

'One of the main educational tasks of the primary school is to build on and strengthen children's intrinsic interest in learning and lead them to learn for themselves rather than from fear of disapproval or desire for praise'

(Plowden 1967:196).

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Current education

‘Far from educating children out of the very ways of thinking and acting which we want to see much later in their lives, we could decide to ensure that such EHoM are cultivated *throughout* school life, wherever they may occur. Designing, making and tinkering are what children do instinctively.’

(Lucas, Hanson and Glaxton 2014, p11)

Too much of the teaching concentrated on pupils acquiring unrelated skills in order to pass tests and examinations but did not adequately equip them with the necessary skills required for either the next stage of their education, work or life, and problem solving and investigative skills were rarely an integral part of learning mathematics except in the best schools where it was at the ‘heart’ of the learning process. (Ofsted, 2012)

Discussion 5

- Does the current South African education system prepare potential engineers to resolve these challenges?
- Positive aspects
- Challenging aspects of pre-university education

Transition to University – Student perspective

Education is about passing exams

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Discussion 6

- What are the challenges you face with the student transition from school to university?

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Managing Student Expectation

Challenges:

- Lack of experience of working in teams.
- Lack of genuine problem solving experience.
- Developing procedural knowledge and skills towards a stronger conceptual base.

Discussion 7

How do you encourage problem solving activities with your students?
What is your experience of student group/team work?

Our expectations of students

Students to engage with problem resolution

Students to engage and contribute within a team

Team to decide on roles

Teams to produce a poster outlining their resolution

Teams to discuss their resolution and answer questions from assessors

Teams to meet and work outside of allocated lab time

Staff challenges

Managing student team work
Appropriate assessment
Designing an appropriate curriculum that is fit for purpose
-ILO’s, Programme aims etc

Where does Mathematics fit in?

Mathematics fantastic vehicle for genuine problem solving activities.

Mathematics at all levels can be applied to engineering problems.

Students with different abilities can make meaningful contributions.

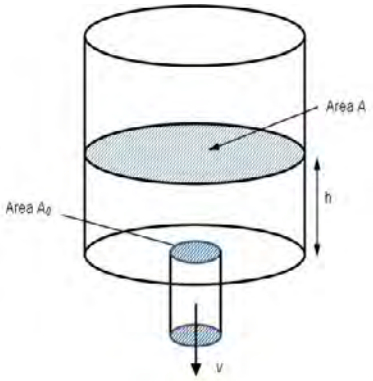
Example of an Engineering problem

Scenario

You have decided that you have had enough of living the 'rat race' culture prevalent in the UK. You have done some investigative work and decided to move to Northern Belize, buy some land and build a new life where you are in control.
One of the first tasks, after building a shelter, is to build a water storage tank so you can have fresh water all year round.

In your investigations you found out that Northern Belize has a rainy season between June and November where, on average, 1524mm of rain falls.

You decide upon a cubical tank with a water outlet at the bottom. Your initial 'guess' at the dimensions for your tank were: sides 3*m* with a drain hole of diameter 0.1*m*.
Unfortunately you can only find information on a cylindrical tank as shown in the diagram.



Main Task

Using Matlab develop a mathematical model to investigate different sizes of tanks and different flow rates so you have access to water all year round.

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Developing a suitable programme/module

Start with what you expect students to have learnt by the end of the programme/module.

Size of cohort.

Prior knowledge and skills of the students.

How will you assess their ‘learning’

How much time to you have.

What resources are available.

Developing suitable problems

Finding problems which students can relate to.
Appropriate challenge levels.
Time required to produce a sensible resolution.
Resources required.

Some problems

- Cable car
- Aircraft turning
- Chloride concentration
- Conservation of mass
- Drug release
- Electrostatics
- Gases
- Human cannonball
- Overhead Power Lines
- Piston stroke
- Salt concentration
- Water tank
- Wind turbine

Tomorrow…

Developing suitable problems

- Consideration of student competence and confidence
- Challenging (scaffolding) but not daunting

Developing appropriate assessment

- What are you planning to assess? Knowledge, skills, team work, problem solving…

Programme/module design

- How much time will be available. One or two semesters, number of hours per week, profile of cohort

Aston Model

‘Traditional’ lectures and tutorials run in parallel with PBL class.

Help given on problem resolution and working in teams.

Treated as genuine engineering teams.

Students treated as ‘equals’.

How was the class set up?

340 students split into teams – maximum size 6

Each team had a one hour session per week (expected to work outside of this)

Help from Teaching Assistants

How much help were students given?

None for finding mathematics constructs (equations etc)

Guided on how to make assumptions.

Encouraged to adopt a ‘trial and improvement’ attitude of mind.

Encouraged to make ‘sensible’ checks.

Guided in problem solving and working in teams.

Guided on how to produce an Academic poster.

Encouraged to take ownership of the challenge.

Evaluation set up

Field notes kept.

Independent evaluation by colleague.

Students given a questionnaire.

Evaluation

- 182 evaluation questionnaires returned.
- Students were asked about working in teams, problem resolution and learning mathematics.
- They were also asked about their experiences and how they thought it helped towards their development as a professional engineer.

Results from questionnaire

69% thought PBL improved their appreciation of the role of mathematics in engineering.

60% thought PBL made mathematics more interesting.

77% thought PBL improved their mathematics knowledge and skills.

They described their experiences of PBL as ‘challenging’, ‘rewarding’, enjoyable’, ‘hard but fun’, ‘hard at first’, ‘interesting’.

Challenges I faced

Getting the teams organised

Arranging appropriate assistance

Letting teams ‘struggle’ and not intervening too soon

Organising assessment

Summary

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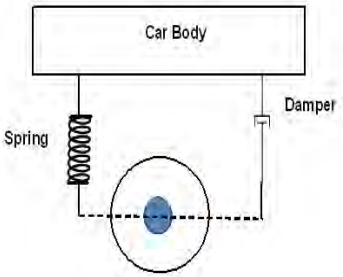
Student PBL journey

For the following function
find $\frac{d^2f}{dx^2}, \frac{d^2f}{dy^2}, \frac{d^2f}{dxdy}, \frac{d^2f}{dydx}$
$f(x,y) = x^4 + xy^3 + 2x^3y^2$



Develop a mathematical model to describe how a car's suspension behaves going over a speed hump.

Challenges for students:
Project planning, conflict resolution, making assumptions, no right or wrong answer, 'having a go', interpreting results.

Students learn:
Persistence, resilience, confidence, team working, resolutions rather than answers, project planning, making assumptions, performing 'sensible' checks.

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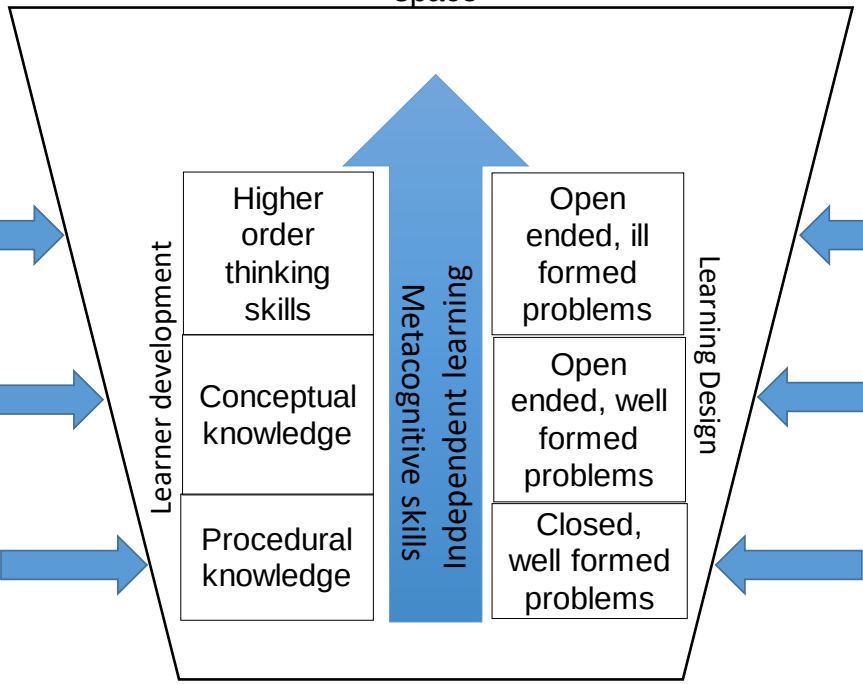
Student Centred:
Discursive, collaborative learning space

HOTS: Analysis, evaluation, synthesis. Critical thinking, problem solving.

Conceptual knowledge: Learning that involves understanding and interpreting concepts and the relations between them.

Procedural knowledge: Learning that involves only memorising operations with no understanding of underlying meanings



Model the current flow in a river

What type of equation would you use to solve a heat transfer problem?

Factorise the following…$x^2 + 3x + 2$

Teacher Centred:
Knowledge transmission learning space

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Peters (2016)

Future Development

PBL approach developed in subsequent years.

Greater alignment with Mathematics and subject specific subjects.

> for example, at Aston we plan to integrate the CDIO approach in Mechanical Engineering with Mathematics.

Move away from Intended Learning Outcomes to Competencies.

Develop a more holistic approach to Engineering Education.

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UCL approach

- Challenges

Questions?

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Integrating MATLAB Into First Year Engineering Mathematics:

A Project Management Approach to Implementing Curriculum Change

Abel Nyamapfene

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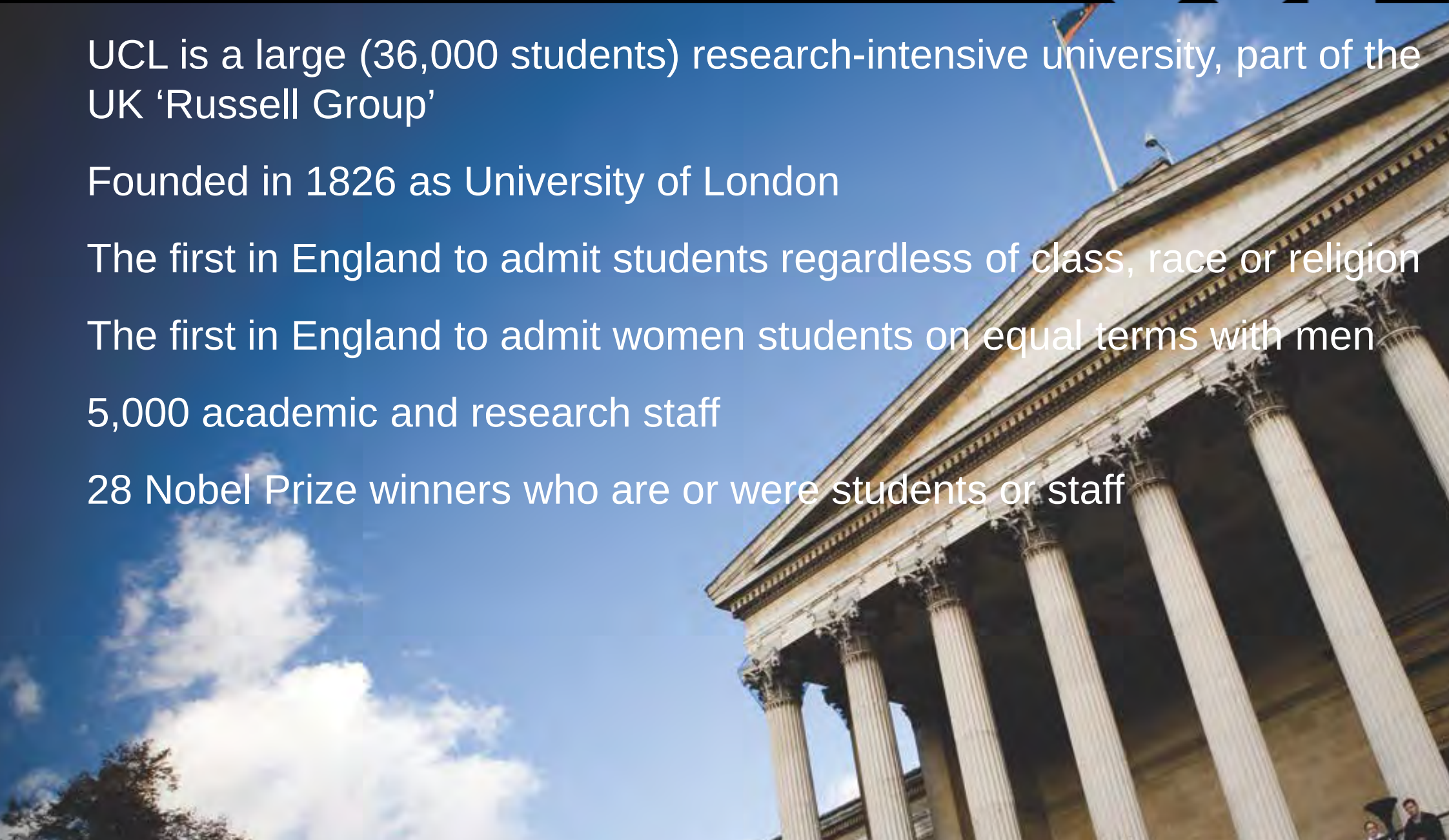
Contextual Background:

Curriculum change within the Faculty of Engineering Sciences at a UK Research Intensive University

LONDON'S GLOBAL UNIVERSITY

UCL



UCL is a large (36,000 students) research-intensive university, part of the UK 'Russell Group'

Founded in 1826 as University of London

The first in England to admit students regardless of class, race or religion

The first in England to admit women students on equal terms with men

5,000 academic and research staff

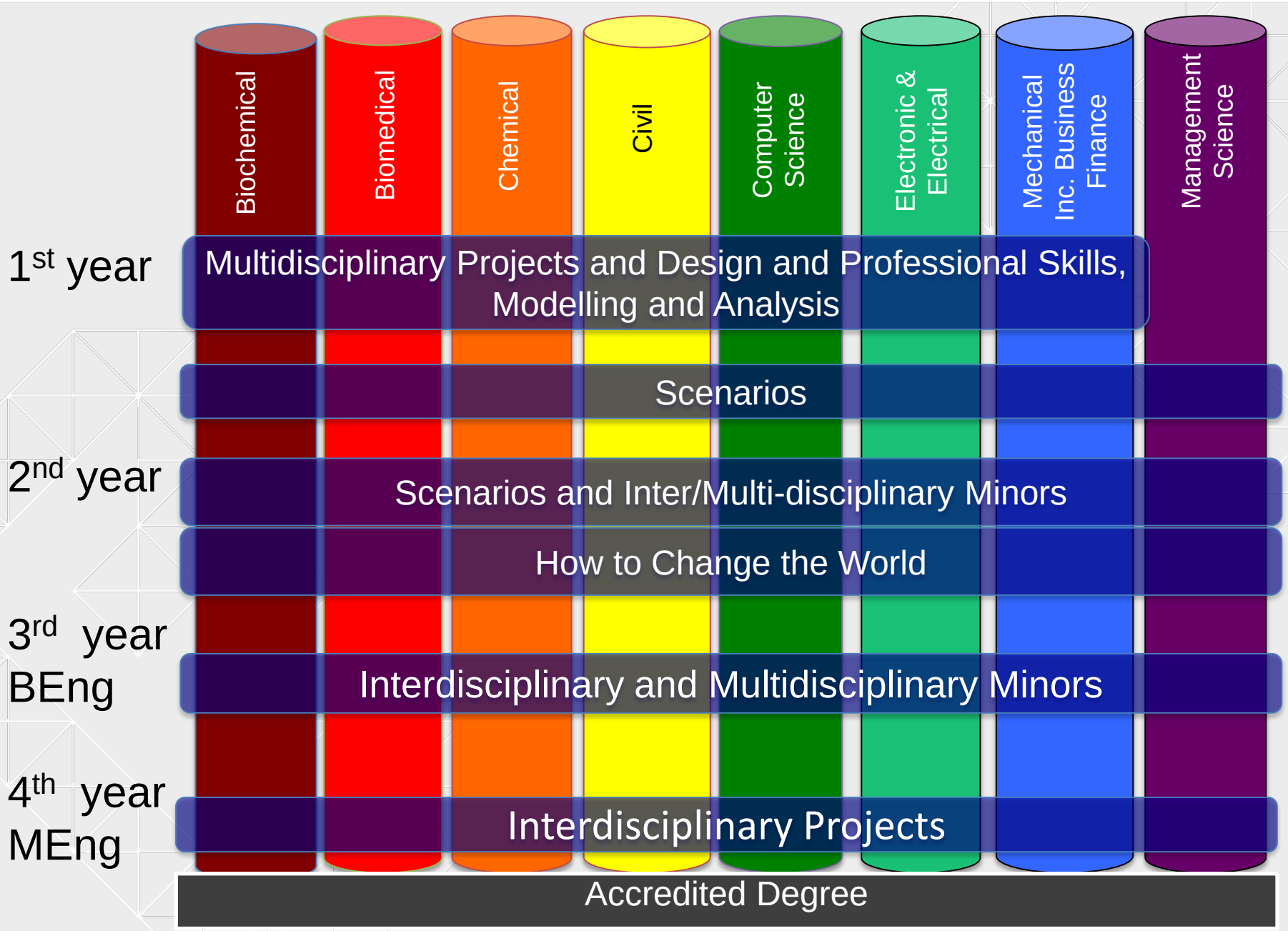
28 Nobel Prize winners who are or were students or staff

Curriculum Change Project:

The Integrated Engineering Project

- A way of teaching that provides connecting activities between the different disciplines
- A common curriculum structure that promotes practical application and transferable skills alongside fundamental theoretical/technical knowledge

Integrated activities



The Mathematics Curriculum Change Project

- Aim: To develop students able to apply mathematical concepts to Engineering problems
- Emphasis on both theory and application
- Problem-based learning approach:
    - Headline Lectures by Research Active Academics
    - Contextual problem solving individually or in group within the Departments
    - Integrated use of mathematical software tools e.g. MATLAB and Excel

First Year Mathematics Course Design

Total contact time: 40 hrs made up of lectures (20 hrs) and tutorials (20 hrs).

Lecture Streams: Three streams of up to 200 students each per week

Tutorials: 2 hr sessions per week to be devolved to departments. Activities to include:

- Problem sheets - student work individually and in groups
- Matlab/ Excel problem solving - individually and/or in groups
- Contextual problem solving in groups with peer assessment

MATLAB Integration Plan

- Redesigned lectures to ensure that Matlab tuition blends in with mathematics tuition
- Used a two-step approach in both lectures and workshops: Introduce mathematical concepts are Follow up with short MATLAB examples
- Emphasise Use of MATLAB single line commands, building up to simple programmes
- Assess MATLAB in continuous course assessments

MATLAB Support for Students

- Sheet with list of key MATLAB commands to be covered in course
- MATLAB “How To” step by step videos
- Walk-in Help Desk support
- Continual weekly progress monitoring and review with all the staff on the module
    - Led to introduction of focussed weekly MATLAB sessions

Outcomes for the First Year

- Initial scepticism from both staff and students to the integration process
- Scepticism compounded by:
  - MATLAB exercises and problem sets were too ambitious
  - Difficulties covering both mathematical concepts and MATLAB instruction in lectures
- Corrective Actions:
  - Reduces complexity of exercises
  - Introduced additional MATLAB sessions
- Immediate Outcomes
  - Students found course challenging but appreciated MATLAB usefulness
  - Delivery of other fundamental courses eased by students' MATLAB proficiency

Outcomes of End of Year Module Review

- Introduced weekly Matlab support lectures
- Standardized departmental weekly tutorial worksheet:
  - Specified level of coverage of each topic and the required introductory MATLAB applications for each week
  - Each worksheet was specifically designed to ensure that the average student would manage to go through it within the 2-hour workshop period.
- Students encouraged to use Matlab routinely to check the correctness of their own paper and pencil computations.

Lessons Learnt

- Introducing change within a cross-faculty module is a non-trivial task
- Adopt appropriate change management techniques to
  - Mitigate staff and student resistance
  - Anticipate and mitigate impact of arising teething problems
  - Secure and maintain top management support throughout change process
  - Emphasise buy-in from both staff and students

Discussion And Question Time

Thank You

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Team-teaching on a Large Multidisciplinary Engineering Mathematics Class:

The Lessons We Have Learnt So Far

Abel Nyamapfene
University College London

Study Objectives

Engineering classes are often delivered through large class teaching

Team teaching is often the preferred mode of delivery, however this aspect is currently under-researched in engineering

This study assesses the effectiveness of team teaching on a large first year mathematics class and to recommend areas for improvement

Definition of Teaching Team

"A group of two or more persons assigned to the same students at the same time for instructional purposes in a particular subject or combination of subjects."

(Johnson & Lobb, 1959)

Team-Teaching may Involve

Members of the teaching team **collaborating** and working **cooperatively** on all, or only on some aspects of teaching and assessment, including course design

(Perry & Stewart, 2005)

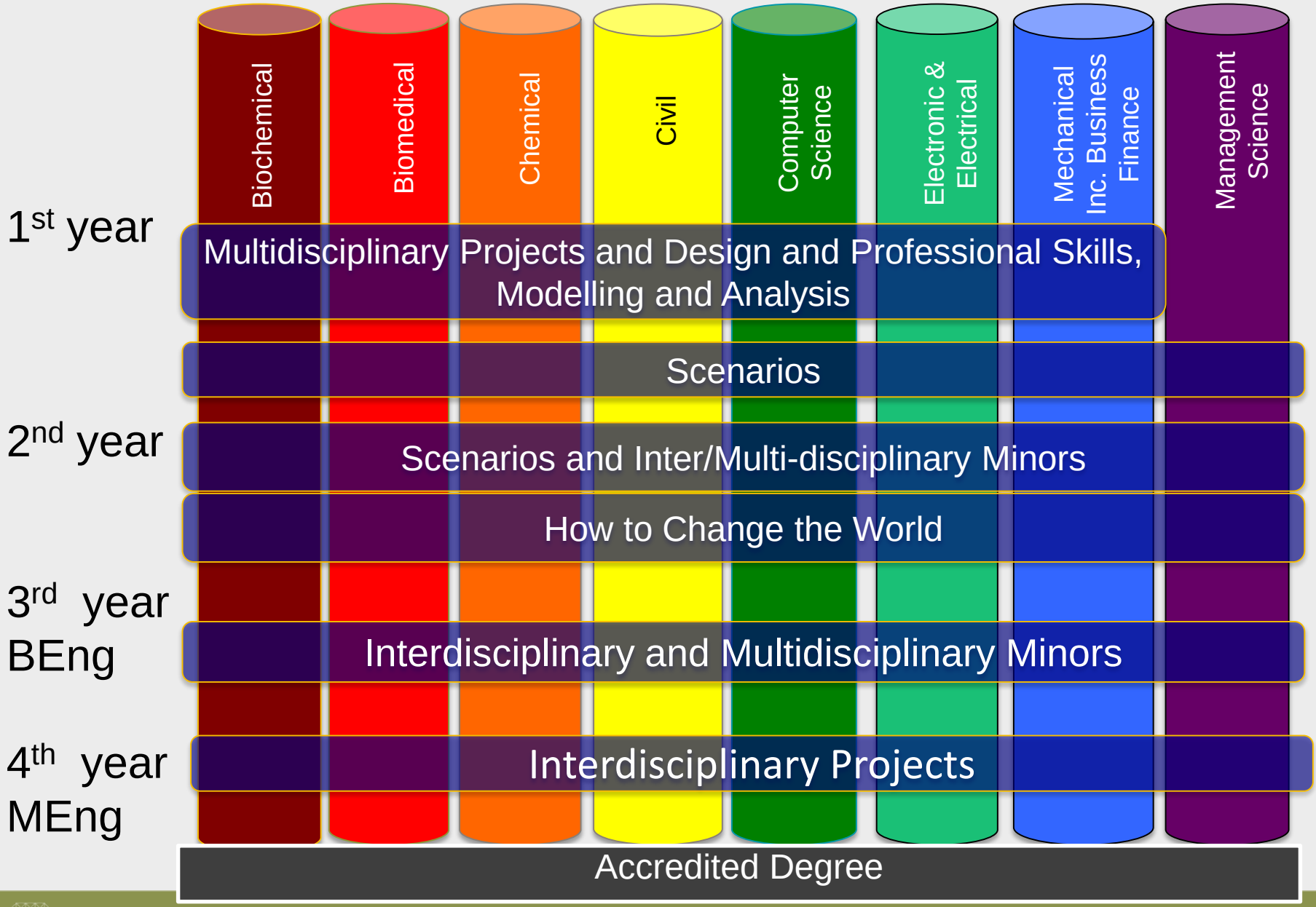
Contextual Background

IEP Integrated Engineering Programme

A way of teaching that provides connecting activities between the different disciplines

A common curriculum structure that promotes practical application and transferable skills alongside fundamental theoretical/technical knowledge

Integrated Activities



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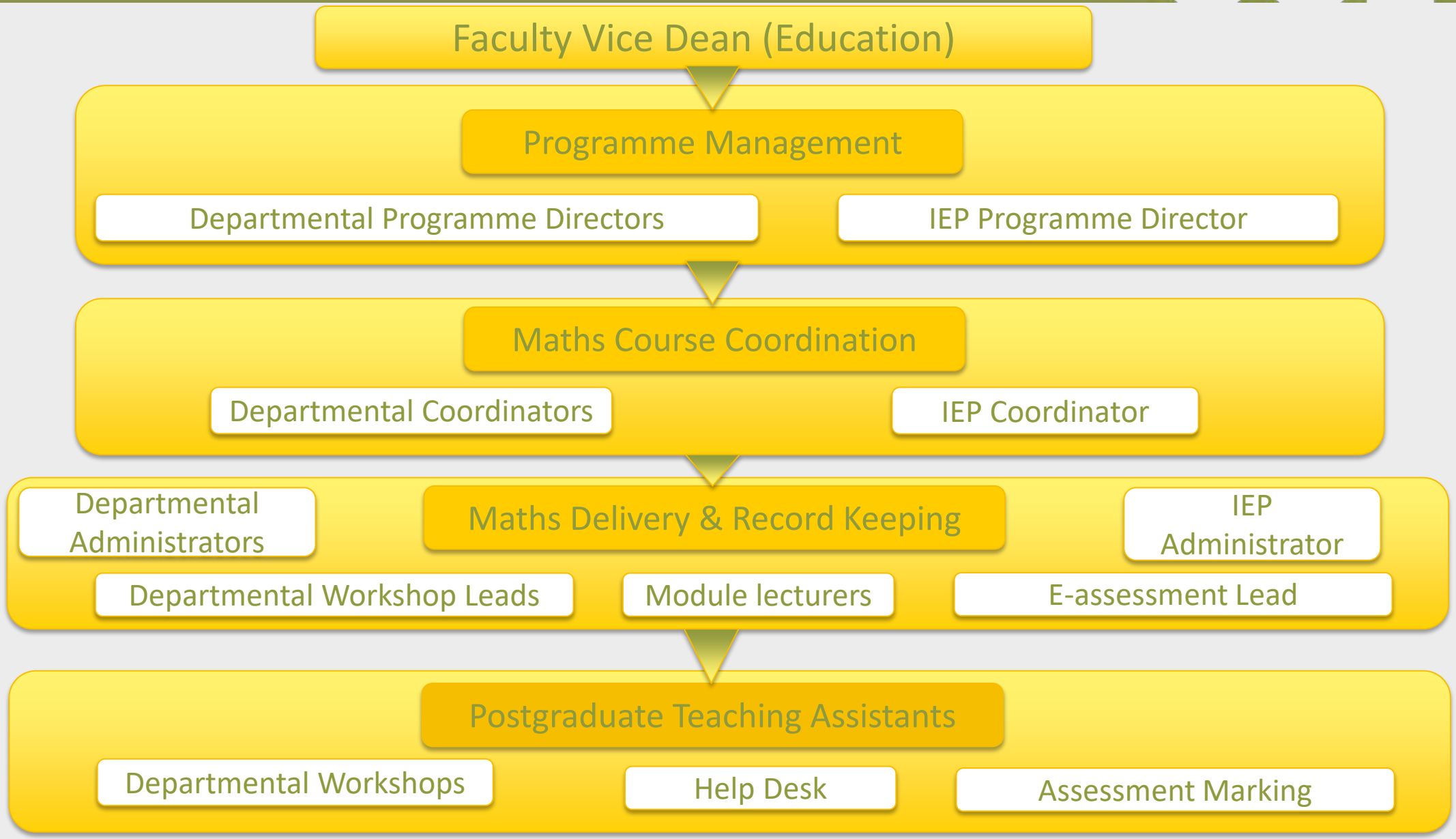
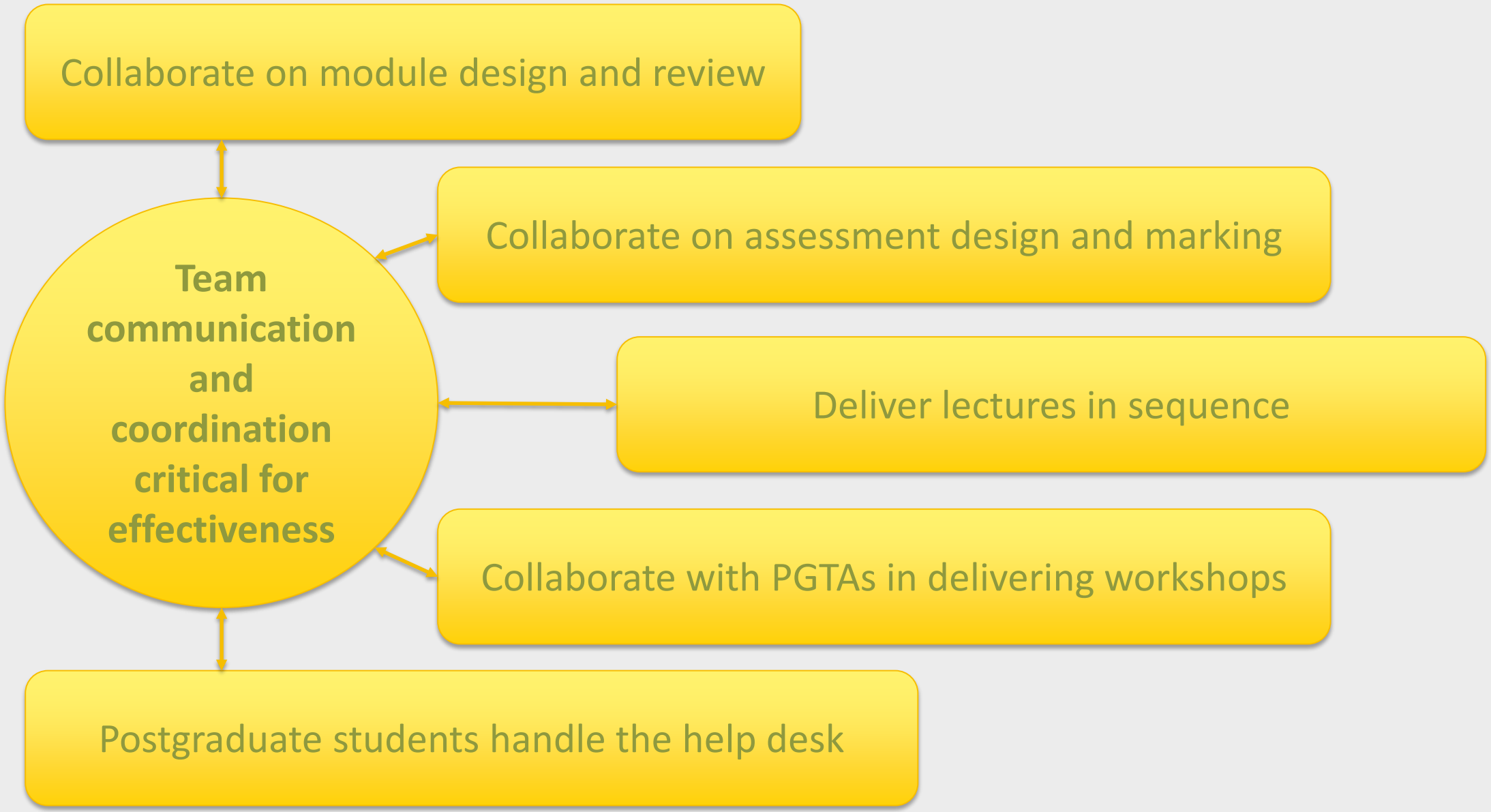
Module Organogram



Team Teaching within the Module



Areas of Team Conflict and Non-congruence

Mathematics Curriculum

Discipline-based and personal differences pertaining to coverage, depth, philosophy/belief systems pertaining to the teaching mathematics, balance between theory and practice, use of computer algebra systems in mathematics teaching

Teaching Methodologies

Variable competence and familiarity with advocated teaching methods e.g. flipped learning, and collaborative active learning approaches

Organisational and Communication Issues

Poor team coordination and communication, lack of shared team response/approach to emerging course delivery issues, lack of team rapport and non-compliance with deadlines leading to disjointed, non-cohesive course delivery

Lessons Learnt

Increased Complexity

Large class team teaching can present significant management and communication challenges

Importance of Team Rapport

Whereas in sole teaching modules it is not critical to maintain rapport with fellow academics, in the case of team-teaching rapport and clarity of communication between team-teaching members is absolutely critical to effective delivery of learning

Effective Management is Critical

When team teaching is implemented on large classes, aspects of module management such as module planning and coordination, staff-student and staff-staff communication, task scheduling and compliance with deadlines become infinitely more important.

Discussion and Question Time

Thank You