

# The Challenge Facing Engineering Educators Everywhere

–The UNESCO Experience

Emeritus Professor David Beanland AO ATSE Aust.






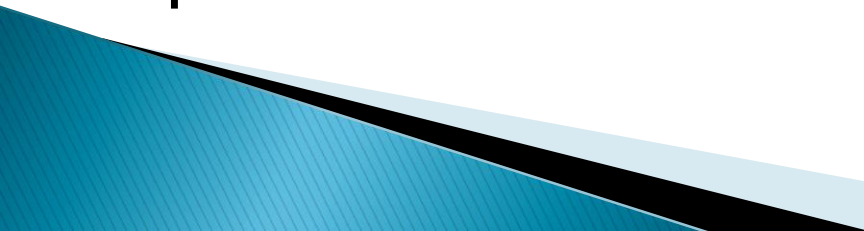
# What is the UNESCO Experience?

- ▶ In 2010 UNESCO published “Engineering–Issues, Challenges & Opportunities for Development”
- ▶ This included many references to the need for a transformation in engineering education
- ▶ I was commissioned by UNESCO to write a book titled “Engineering Education: Transformation and Innovation” in 2011
- ▶ This has provided the opportunity to explore engineering education as a system, its goals, its achievements, its problems and to contemplate approaches which could be effectively utilised.


# What were some of the issues identified when preparing the UNESCO monograph?

- ▶ Students currently consider engineering education to be boring & the profession does not appeal to those interested in social responsibility.
- ▶ Engineering courses are considered to be difficult, consequently many students choose to avoid them.
- ▶ Current engineering education programs are heavily weighted toward the presentation and learning of specialised technical detail.
- ▶ Engineering practice however, requires multi-disciplinary knowledge and the abilities to evaluate, be creative, to learn what is relevant as necessary, and then to be able to apply this knowledge responsibly and efficiently in a specific project.

- ▶ There are many reports suggesting that engineering education needs to be transformed, including UNESCO, RAE(UK), NAE, NSF, IEEE (USA), Eng. Aust. & the Carnegie Foundation.
  - ▶ Engineering curricula are often overloaded as a result of the technology explosion.
  - ▶ High failure rates are common.
  - ▶ Content focussed on the skills required for the practice of professional engineering is commonly minimal.
  - ▶ Employer surveys indicate that they are dissatisfied with the capabilities demonstrated by graduates.
  - ▶ Work experience in courses is valued but uncommon.
  - ▶ Relations between employers and universities are not strong.
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- ▶ The essential graduate attributes of engineers have been agreed internationally, for those countries participating in the Washington Accord, but they are not adequately addressed or assessed.
  - ▶ Engineering education programs have changed little over 40 years & have been slow to utilise IT resources to facilitate student learning.
  - ▶ Engineering education research, however, has proven some very effective approaches.
  - ▶ Unfortunately there are very few exemplary engineering education programs where these practices have been adopted.
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- ▶ Project Based Learning is a proven approach to enhance engineering education. It enables students to act in teams as engineers-in-training throughout their program, commencing on day one.
  - ▶ Projects can provide the driver for students to participate in inquiry-based learning.
  - ▶ Information on every engineering topic is accessible on the web.
  - ▶ Facilitated student learning should be the focus, not staff lecturing.
  - ▶ Some universities (eg MIT & Stanford) are offering their entire programs by web-based learning, without charge.
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# Principles to Guide Transformation

1. The objectives of engineering education become the Washington Accord Graduate Attributes (or equivalent)
2. Curriculum design maximises the development, and progressive assessment, of these essential capabilities by each student.
3. The design & implementation of the first year of engineering education maximises student motivation.
4. Project Based Learning is utilised as at least 25% of each semester of engineering education programs.
5. Lectures are replaced by activities that generate inquiry-based learning through the active involvement of students.
6. Information & communication technology is utilised to facilitate student centred learning.




The **Washington Accord** indicates that each graduate should possess the following attributes:

1. Engineering knowledge
2. Problem analysis
3. Design/development of solutions
4. Investigation
5. Modern tool usage
6. The engineer and responsibility to society
7. Environment & society
8. Ethics
9. Team member and leader
10. Communications
11. Project management & finance
12. Life-long learning

# What changes are required?

- ▶ Use of **Project Based Learning** as the core of the engineering curriculum in each semester.
- ▶ Use of the available **ICT** resources to provide student-centred inquiry-based learning.
- ▶ Staff to act as **learning facilitators**: no lectures!
- ▶ Focus is upon the **development and assessment** of the essential graduate attributes.
- ▶ Provision of a **home-room** for learning/work space to enable student interaction.
- ▶ **Promotion** of engineering as an essential, exciting, rewarding & responsible profession.

- ▶ **Relations with employers** are improved to include work place visits, project work, staff exchange, computer software access, specialised project facilities.
  - ▶ **Work experience** modules are included for all students.
  - ▶ **Clear goals** are established for each student, based on WA graduate attributes and the student's career goals.
  - ▶ Students progress toward them is progressively assessed using **formative assessment**.
  - ▶ The **e-Portfolio** concept is used to record the student's goals, achievements and assessments.
  - ▶ The technical content of the student's program is arranged to support the PBL stream.
  - ▶ Education is given parity of status with research, for staff in universities.
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# Structure of a Typical PBL Engineering Degree Program

Semester	Projects (25-50%)	Engineering Principles		Mathematics , Science Project Management
1	Environmental Systems	Engineering Systems	Mathematics	Physics
2	Information Technology Systems	Information Technology	Mathematics	Chemistry
3	Mechanics Structures	Electrical Power	Structures & Mechanics	Teamwork & Communication
4	Electrical & Electronic Systems	Electronics & Sensors	Transport & Infrastructure	Environment
5	Specialisation	Core Discipline Specialisation Units		Project Management
6	Specialisation			Manufacture & Implementation
7	Specialisation			Business & Financial Considerations
8	Final Design and Project Realisation			Ethics & Social Responsibility

# Changes in Engineering Education

- ▶ are essential
- ▶ are major in scope
- ▶ are difficult for universities to introduce

Their realisation requires:

- ▶ the commitment of Academies and Accrediting Authorities
- ▶ the participation of employers
- ▶ the support of governments
- ▶ the commitment and skill of academic staff
- ▶ changes in university policy and practices

# What is preventing implementation?

- ▶ Universities have their primary focus on research and not education.
- ▶ Staff resist change from established practices.
- ▶ University culture expects and rewards lecturing.
- ▶ Engineering capability is considered to be demonstrated by examination results.
- ▶ Accreditation authorities do not enforce the achievement of the essential graduate attributes by each graduate.
- ▶ University leadership has not recognised the need for transformation, or considers it too hard.
- ▶ University space is designed for lecturing.
- ▶ Rewards for effective educators in universities are limited currently.



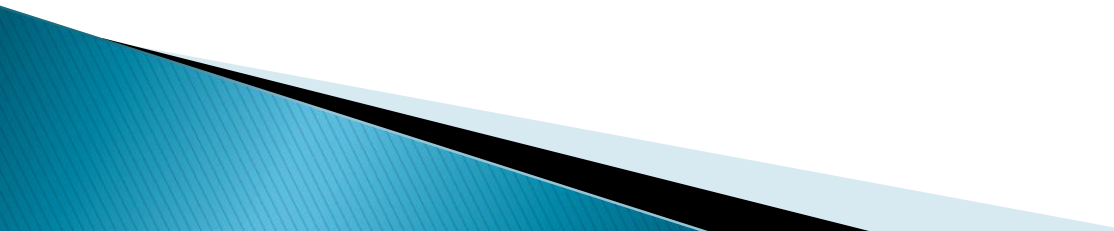
## Issues that must be addressed when implementing transformational change in university programs

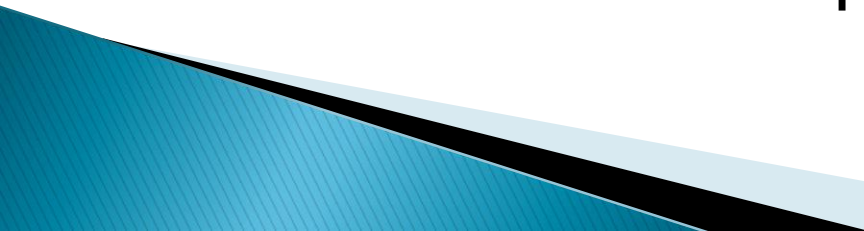
Vision +	Consensus +	Skills +	Incentives +	Resources +	Action Plan +	= Change
	Consensus +	Skills +	Incentives +	Resources +	Action Plan +	= Confusion
Vision +		Skills +	Incentives +	Resources +	Action Plan +	= Sabotage
Vision +	Consensus +		Incentives +	Resources +	Action Plan +	= Anxiety
Vision +	Consensus +	Skills +		Resources +	Action Plan +	= Resistance
Vision +	Consensus +	Skills +	Incentives +		Action Plan +	= Frustration
Vision +	Consensus +	Skills +	Incentives +	Resources +		= Treadmill

From. Thousand, J.S., and Villa, R.A. (1995). Managing Complex Change Towards Inclusive Schooling, in: R.A. VILLA and J.S. THOUSAND, *Creating an Inclusive School*, Association for Supervision and Curriculum Development (ASCD).

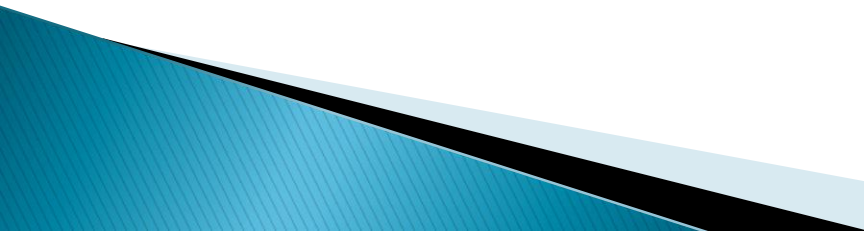
# What can Accrediting Authorities do?

- ▶ Accept that a transformation of EE is required and that the Accrediting Authority has the responsibility for its implementation by ensuring that the WA (or similar) graduate attributes are developed by all graduating students by 2018.
- ▶ Promote to government the importance of their funding a trial project to develop, demonstrate and implement a strategy for collaborative EE transformation.
- ▶ Promote, encourage and facilitate the necessary transformational change in universities.
- ▶ Encourage the growth of EE programs.

- ▶ Encourage employers to work with universities to implement change.
  - ▶ Review the current approach to Engineering Technologist and Engineering Associate programs.
  - ▶ Actively promote understanding of the engineering profession in the community.
  - ▶ Utilise universities to play a larger role in preparing graduates for Chartered Status in their post-graduate programs.
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- ▶ Encourage the provision of more general engineering education in years 1 & 2, followed by 2 years of focusing upon the specialist discipline.
  - ▶ Support collaboration between universities to minimise their costs while maximising their effectiveness.
  - ▶ Encourage universities to have integrated programs for engineering/ technology/education for the preparation of teachers for secondary education STEM.
  - ▶ View the transformation of engineering education as an opportunity that is intimately related to the advancement of the profession.
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## Advantages of this approach to EE Transformation

- ▶ The inevitable impact of IT upon universities is utilised in the most effective way.
  - ▶ The cost of engineering education is reduced.
  - ▶ Collaboration and exchange of students internationally is facilitated.
  - ▶ New engineering programs can more easily utilise transformed programs.
  - ▶ University–engineering employer interactions can benefit both parties and the graduates.
  - ▶ Both the esteem and understanding of the engineering profession can be enhanced.
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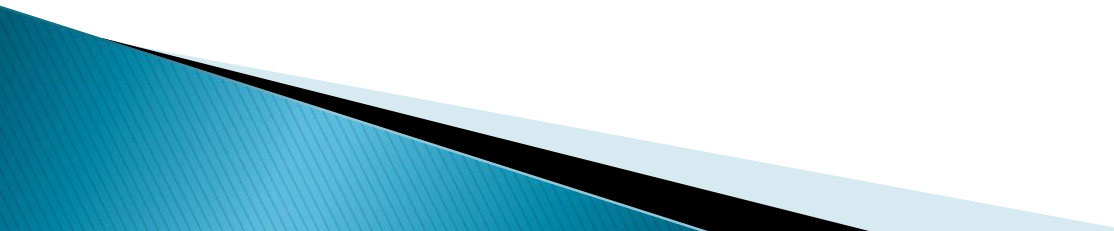
# CONCLUSION

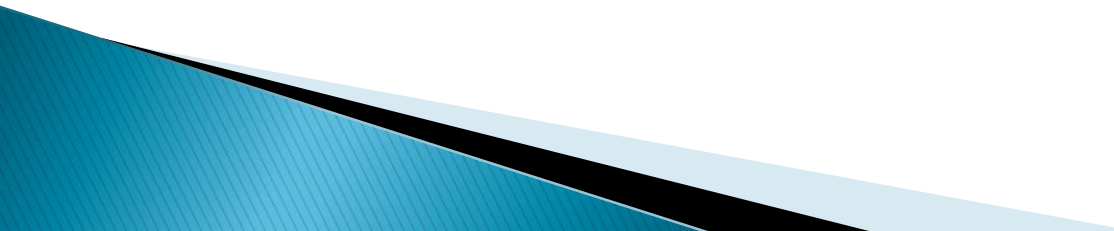
- ▶ The community, the employers, the students & the profession need a **transformation** of university education.
- ▶ Universities require **external incentives/assistance** to achieve major changes in their current practices.
- ▶ Effective student-centred learning can be achieved by using Project Based Learning and ICT resources.
- ▶ Accreditation that **examines/requires** the achievement of the required graduate attributes by each student is strongly recommended as the means of triggering change.
- ▶ A demonstration trial should be established to produce an exemplar of the changes required for implementation through **collaboration**.




# We need to envisage the future which we desire

- ▶ Exemplars: Singapore University of Technology and Design, Franklin W Olin College, Aalborg Univ, CDIO.
- ▶ Engineering as an attractive program for students.
- ▶ Students responsible for their learning.
- ▶ Staff responsible for program design which can provide student-centred learning experiences to assist their development as engineers, while providing the essential guidance and assessment.
- ▶ Broad first two years to learn how to learn and how to act as an engineer.

- ▶ Specialist final two years to develop technical competence and understanding.
  - ▶ Course objectives are the WA Graduate Attributes.
  - ▶ Their progressive assessment is recorded in Student's e-Portfolio.
  - ▶ Projects (PBL) in all semesters.
  - ▶ Technical facilities upgraded for analysis, measurement, design, fabrication & development.
  - ▶ Use of web-based learning materials.
  - ▶ Cooperative collaboration to share good ideas.
  - ▶ Compulsory work experience and interaction with experienced engineers during the program.
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- ▶ Students communicate with and learn from each other.
  - ▶ Students are supported to become leaders.
  - ▶ Students interaction is encouraged as learning occurs in their home room and on the web.
  - ▶ Graduate education is designed to facilitate attainment of Chartered Engineer registration.
  - ▶ Engineering faculties cooperate in Secondary STEM teacher education.
  - ▶ Learning to be an engineer becomes exciting for male and female students.
  - ▶ Graduates are committed to contribute responsibly to their society's development.
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# To Achieve Engineering Education Transformation:

- ▶ Universities must change.
  - ▶ Accrediting Authorities should support them by requiring the realisation of the Washington Accord Graduate Attributes (or equivalent) to be demonstrated by each graduating student.
  - ▶ Governments must understand the critical need for an appropriate supply of effective engineers and provide appropriate support for the transformation of engineering education.
  - ▶ Employers must commit to working with universities.
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# The TRANSFORMATION of ENGINEERING EDUCATION is DIFFICULT

Our students deserve it

Our profession requires it

Our communities need it

It is the RESPONSIBILITY of the UNIVERSITIES to TRANSFORM Eng. Ed.

But they will need the assistance of:

Accrediting Authorities

Employers

Government

The Profession