Specification and Assessment of Outcomes-based Engineering Curricula for Program Accreditation

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OVERVIEW

Outcomes-based engineering education:
- constructive alignment for program and unit design
- international frameworks and benchmarking
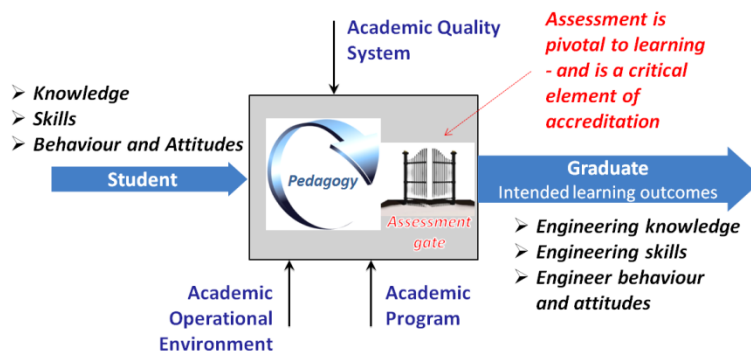- tools for program specification and mapping.

Challenges of outcomes assessment:
- improving examinations
- assessing authentic/simulated projects
- projecting beyond graduation horizon.

Improving practice :
- education and training for academics
- sharing best practice.

## Model of Engineering Education (+ Accreditation)

Outcomes-Based Education
- is the "spirit of [good] education"
- is the "emerging reformation model"

- is learner-centric and holistic
- focusses on competence of the individual
- but encourages cooperative learning
- is consistent with Bloom's taxonomy
- is "constructivist" (with [educator-driven] alignment of objectives, pedagogy and assessment)
- is consistent with Indian traditions of education.

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Dr Ketan Kotecha, Dr Richa Mishra,
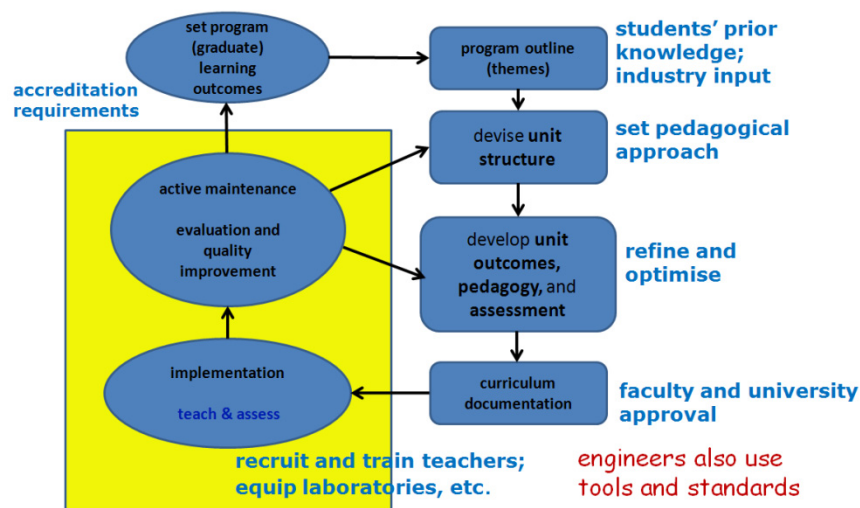Institute of Technology, Nirma University Newsletter

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OBE is Implemented by "Constructive Alignment"
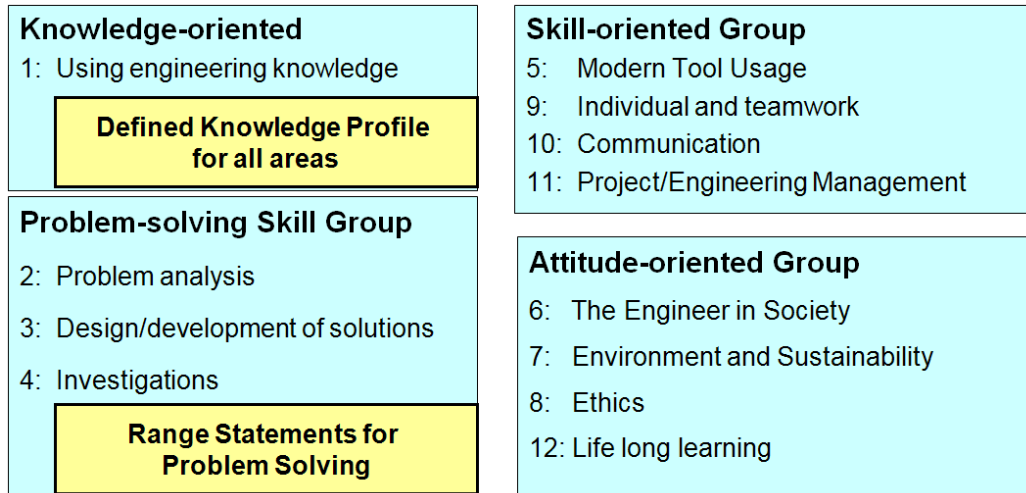

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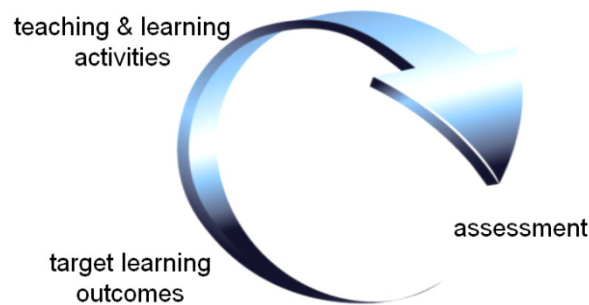
After Biggs and Tang, Teaching for Quality Learning at University (4ᵗʰ ed. 2011)

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- define target outcomes
- choose suitable teaching methods (pedagogy) and content that are as active and authentic as possible
- align assessment tasks with target learning outcomes

OBE Aligns with Engineering Design Process

Graduate Outcome Areas in the IEA Accords

Knowledge-oriented
1: Using engineering knowledge

> **Defined Knowledge Profile for all areas**

Problem-solving Skill Group
2: Problem analysis
3: Design/development of solutions
4: Investigations

> **Range Statements for Problem Solving**

Skill-oriented Group
5: Modern Tool Usage
9: Individual and teamwork
10: Communication
11: Project/Engineering Management

Attitude-oriented Group
6: The Engineer in Society
7: Environment and Sustainability
8: Ethics
12: Life long learning

- achievement is defined for each outcome in each Accord
- Accord signatories operate accreditation systems that test substantial outcomes equivalence to the Accord "exemplar"
- similar frameworks are defined by ENAEE (EUR-ACE) and CDIO.

OBE Mapping of Target Outcomes

Assigning a target level of attainment (e.g. 0 – 5) to each graduate attribute for each program unit provides a good way of developing outcome themes, and choosing pedagogy and aligning assessment tasks.

Prgram Unit (examples)	Science & Maths	Engin'g Science	Engin' Applic'n	Problem Anaysis	Design	Comm- Unication	Team- Work	...
Maths 1	2	1	1	1	0	0	0	
Mechanics 1	2	2	1	1	0	1	1	
Systems 1	2	2	2	2	1	0	0	
Design 2	0	0	1	3	3	2	3	...
Project Man'g	0	0	0	3	3	3	3	...
...								
...								
Program target	**3**	**4**	**4**	**4**	**4**	**4**	**4**	...

Example levels: *0 - none, 1 - basic, 2 - developed, 3 - competent/fluent, 4 - professional/complex, 5 - advanced (postgraduate).*

OBE Program and Unit Mapping Tool

Used for peer review, refinement, approval

Courtesy: Australian Council of Deans of Science

In general, engineering educators are good at outcomes specification and mapping, are quite innovative with pedagogy (with more project work), but need to improve assessment practices and share their expertise

In-program assessment drives students' focus and learning behaviours – basic questions:

- Does (unit) assessment align with learning outcomes?
- Does the combination of unit assessments match the overall outcomes targets?
- Is the assessment (over the whole unit and program) inclusive of the range of students' learning styles?
- Are assessment tasks authentic with respect to engineering practice, especially in group tasks and project work?
- Are the threshold and higher levels of assessed attainment defined for students?
  - What does "50% pass" mean in terms of "competency" in a task or behaviour?
- Can all assessment tasks be formative and encourage greater self-reflection – especially in major project work?

Broader Questions and Issues

- Despite assessment covering all target outcome areas, employers may question typical engineering graduates' demonstrated ability in:
  - communications, teamwork and project management
  - understanding of business practice.
- So rarely do they question abilities in technical knowledge and skills, should we assume these are broadly satisfactory?
- Can (some) target program outcomes be assessed directly?
  - What further insights to the education process do registration and licencing examinations provide?
  - Are generic or discipline specific graduate assessment instruments useful?
- External Examiners and Accreditation processes provide some inter-institutional benchmarking of assessment – how can this be exploited to increase reliability and standards?

Approaches and Tools for Improved Assessment

- Bloom's (revised) taxonomy provides action verbs for cognition at progressively higher levels.
  - Within each level, further verbs guide learning activities within the contexts of experience and prior knowledge.

The Knowledge Dimension	The Cognitive Process Dimension					
	1. Remember	2. Understand	3. Apply	4. Analyse	5. Evaluate	6. Create
A) Factual Knowledge						
B) Conceptual Knowledge						
C) Procedural Knowledge						
D) Metacognitive Knowledge						

tests and examinations dominate early year units

assignments and projects dominate later year course units

Metacognitive knowledge: awareness of learning and learning strategies, techniques to improve learning, knowledge of one's own abilities and weaknesses, ability to recognise higher and lower level thinking – not much covereage in engineering.

Tools for Improved Assessment

Unambiguous specifications of what is expected:

- clear course (program unit) guides are essential
- examples of assessed work inform students of standards
- clear rubrics provide students and markers with guidance
- see Spurlin *et al.* for examples.

Improving group work:

- effective group work has to be learned – and is a key skill for engineers
- use schema for formulating groups for clear purpose
- use self- and peer- assessment tools to enhance assessment accuracy and students' self awareness (e.g., SPARKPLUS)
- See Kavanagh *et al.*, Willey & Gardner.

Ensure capstone project assessment covers all its intended outcomes.
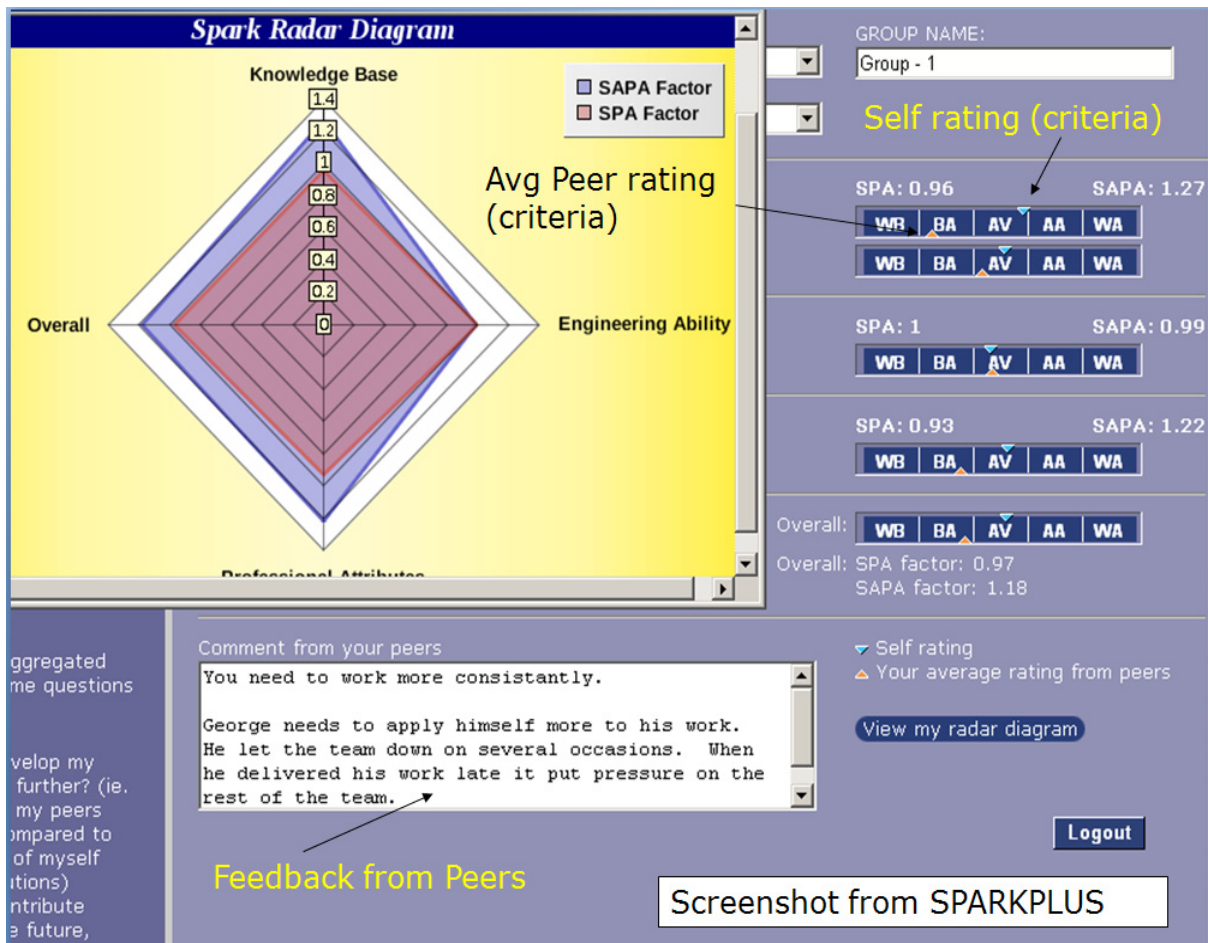
Capstone Projects and their Assessment

- Are increasingly important to students (self-identity and efficacy as beginning engineers).
- Contribute to (all) outcomes in the WA profile.
  - advanced knowledge, (complex) problem-solving, investigation (research), design, tools, communications (multiple forms), attitudes, life-long learning.
- But these are rarely (all) rigorously and reliably assessed.

- A national project in Australia has developed Guidelines for best-practice in BEng(Hons) capstone projects:
  - curriculum – clear outcome and process specifications
  - supervision – focus on mentoring to the student outcomes, with formative feedback
  - assessment – clear rubrics and examples
  - collaborative benchmarking between other supervisors.

Adopting Improved Assessment Practices

- reflect on own and faculty/department assessment practice (*e.g.,* answer questions on slides 11, 12)
- share practice, and benchmark against best-practice
- adopt systematic development activity for individual academics and faculty/department
- familiarity with educational principles and assessment literature (as appended)
- short courses for all and formal higher education qualifications for some
- engage in and disseminate engineering education conferences.

CONCLUSIONS

- Outcomes-based education should underpin improved graduate attainment.
- The engineering profession has agreed international outcomes standards and accreditation systems.
- Educators have created evidence-based literature and resources for curriculum specification, pedagogy and assessment, including for engineering.
- Accreditation indicates that best-practice assessment lags program and unit specification and mapping.
- Individuals and faculties/departments need to reflect on their assessment practices, and take steps to improve.
- This presentation has provided some insights into improving the coverage and reliability of student assessment.

REFERENCES

[1] International Engineering Alliance (2013). *Graduate Attributes and Professional Competencies v3*. see www.ieagreements.org

[2] L Anderson and D Kratwohl (2001). *A Taxonomy for Learning, Teaching and Assessing : A Revision of Bloom's Taxonomy of Educational Objectives*, Addison Wesley, New York

[3] J. Biggs and C. Tang (2007). *Teaching for Quality Learning at University*. McGraw-Hill and Open University Press, UK

[4] E. Crawley *et al*. (2011). *CDIO Syllabus v.2*. www.cdio.org

[5] L. Kavanagh, D. Neil and J. Cokley (2011). *Developing and disseminating team skills capacities using interactive online tools for team formation, learning, assessment and mentoring*. Australian Learning and Teaching Council. See http://www.olt.gov.au/resource-library?text=Kavanagh

[6] K. Willey and A. Gardner (2010). *Investigating the capacity of self and peer assessment activities to engage students and promote learning*. European Journal of Engineering Education 35(4): 429 – 443

[7] J. Spurlin, S. Rajala and J. Lavelle (eds) (2008). *Designing Better Engineering Education though Assessment*. Stylus Publications

[8] M. Rasul *et al*. (2015). *Assessing Final Year Engineering Projects: Ensuring Learning and Teaching Standards and AQF8 Outcomes*. Australian Office for Teaching & Learning. See http://www.olt.gov.au/resource-assessing-final-year-engineering-projects-ensuring-learning-and-teaching-standards-and-aqf8

Prof. Robin King

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Professor Robin W. King was educated in the UK, gaining his PhD in Electrical Engineering from Imperial College in 1972. He worked as a research engineer with the British Broadcasting Corporation and in academic positions in Papua New Guinea and the UK, prior to moving to Australia in 1985. Robin King has held academic positions at the University of New South Wales and the University of Sydney. He was Pro-Vice Chancellor for Information Technology, Engineering and the Environment at the University of South Australia in Adelaide from 1997 to 2007, and on retirement was awarded the title of Emeritus Professor. Robin King now lives in Sydney, and is an Adjunct Professor at the University of Technology, Sydney. Robin King has published more than 150 papers on communications engineering, most notably in multi-disciplinary research areas of speech technology, and on engineering education and accreditation.

Since 2007, Robin King has undertaken several national and international roles to support engineering education and accreditation. He authored a major report national report on engineering education in Australia in 2007. He was the part-time Executive Officer for the Australian Council of Engineering Deans (ACED) for 2008-14, and led several projects on improving aspects of engineering education, including a major collaborative project on improving the quality of engineering students' exposure to engineering practice. During 2009-13 he chaired the International Experts Group for the engineering module of the OECD Assessment of Higher Education Learning Outcomes (AHELO) project. As a Consultant he has facilitated workshops on outcomes-based engineering education and accreditation in Australia, Japan and Thailand, and has given presentations on these topics in Sri Lanka, China, the Philippines, Malaysia and India.

Robin King was elected as a Fellow of Engineers Australia in 1993 and as a Fellow of the Institution of Engineering & Technology (UK) in 2006. He was Chair of the Accreditation Board of Engineers Australia for 2007–12, and Chair of the Sydney Accord for 2001–15. He was Engineers Australia's lead delegate to the International Engineering Alliance annual meetings for 2008–15. He was elected as an Honorary Fellow of Engineers Australia in 2015. In 2011 Robin King was elected as a Fellow of the Australian Academy of Technological Sciences and Engineering, and chaired their Education Forum during 2013–15.