engineering new zealand

MAXIMISING THE VALUE OF CAPSTONE PROJECTS BY DESIGN

Dr Andrew Cleland

My Background

- 23 years as an engineering academic, including successful accreditation as a Dean of Faculty
- 14 years as chief executive of Engineering New Zealand overseeing (and sometimes participating in) accreditation activities
- Major role in International Engineering Alliance
- 7 years as chief executive of New Zealand’s academy for research and scholarship
- 5 years voluntary leadership of accreditation teams

The Evolving Nature of Engineering Practice

An historic definition of engineering (pre-1980):

"Engineering harnesses (and also resists) the power of nature for the benefit of mankind"

Engineers sought to:

- Lift living standards, and
- Protect people
- But their code of ethics was focused on "business" practices

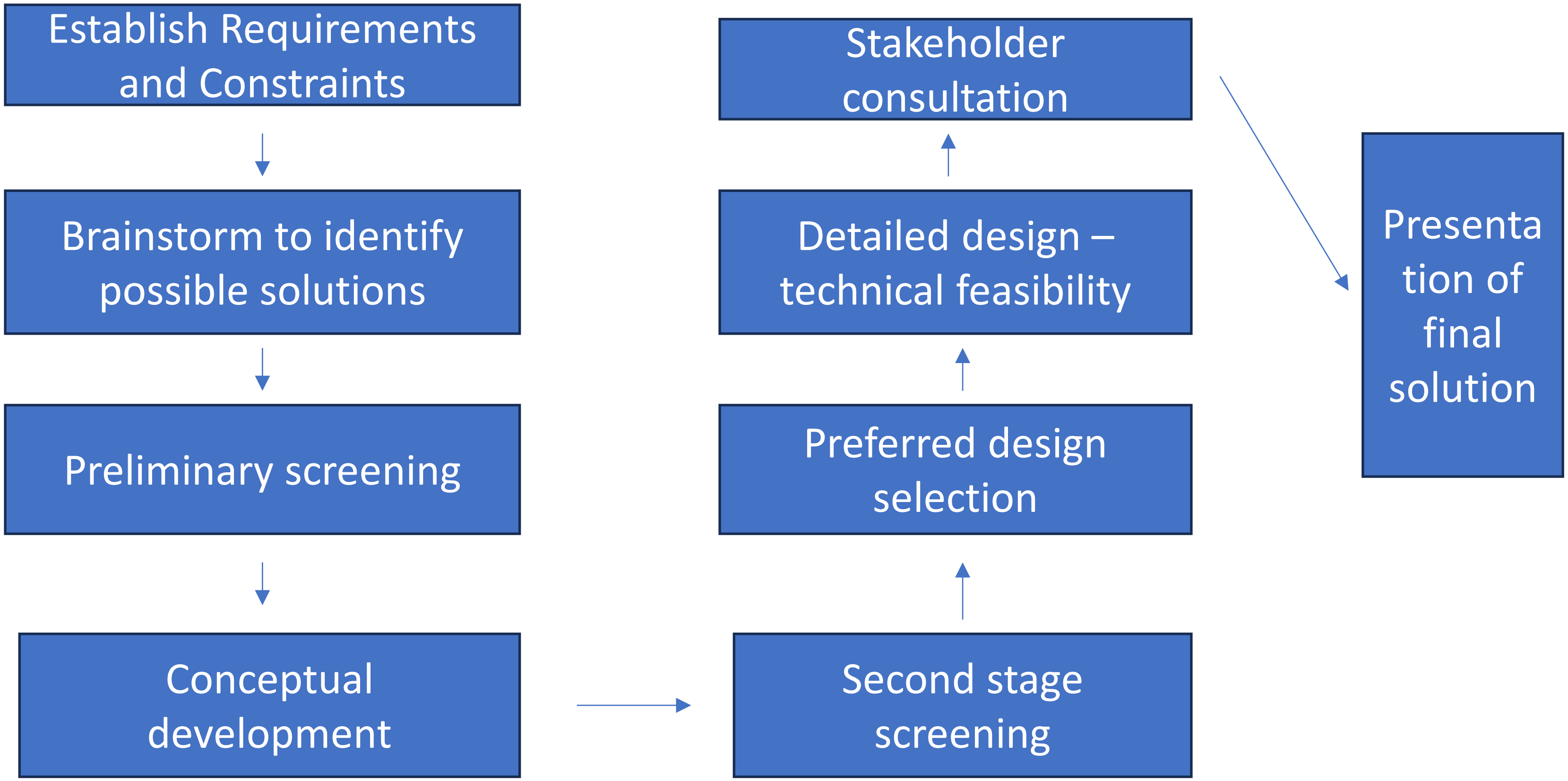
Drivers for Change from 1980 to the Present

- Embracing of importance of sustainability
- Environmental ethics
- A little later, introduction of societal ethics
- And most recently, introduction of cultural ethics

- As well as **<u>doing things right</u>** ….
- Engineers must **<u>do the right things</u>**

But who judges if they are doing the right things?

A Design Process (iterations not shown)



How do Stakeholders contribute? – Case 1

- Interviewed by engineer at start, consulted at end
  - Engineers interpretation of stakeholder perspective is used
  - By time of consultation it is often too late for change
  - Supposedly engineering is being done **<u>for</u>** the stakeholders but really engineering is being done **<u>to</u>** the stakeholders!

How do Stakeholders contribute? – Case 2

- Interviewed by engineer at start, consulted more than once:
  - Engineer checks out interpretation of stakeholder perspective
  - At time of consultation engineer justifies design as meeting the stakeholder-affirmed constraints and requirements
- Engineering is still being done **<u>to</u>** the stakeholders!

How do Stakeholders contribute? – Case 3

- Interviewed by engineer at start, consulted at end, **and**
  - Engineer checks out interpretation of stakeholder perspective
  - Stakeholders asked their view on suitability of options at both preliminary and second stage screening
  - Stakeholders more likely to be listened to at final consultation stage

Engineering is starting to be done **with** stakeholders!

How do Stakeholders contribute? – Case 4

- Engineer and stakeholders co-establish requirements and constraints
- Stakeholders join the brainstorming of design concepts
- Stakeholders participate in decision making at both screening stages
- Final consultation becomes of lesser importance
- This is **co-design**!

Implication for Engineering Education

- WA6 “The Engineer and the World” has become increasingly important in the Accord graduate attribute exemplars
- Design teaching needs to reflect (or even lead) contemporary engineering practice
- Academic skill base needs additionally competence in supervising and assessing integrative capstone project work

WA 3 – Design/development of solutions (V4)

Design creative solutions for complex engineering problems and design systems, components or processes to meet identified needs with appropriate consideration for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations as required.

(drawing on WK5 - Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area)

Complex engineering problems (1 of 2)

Have characteristic WP1 and some or all of WP2 to WP7:

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

WP2: Involve wide-ranging and/or conflicting technical, non-technical issues (such as ethical, sustainability, legal, political, economic, societal) and consideration of future requirements

WP3: Have no obvious solution and require abstract thinking, creativity and originality in analysis to formulate suitable models

Complex engineering problems (2 of 2)

Have characteristic WP1 and some or all of WP2 to WP7:

WP4: Involve infrequently encountered issues or novel problems

WP5: Address problems not encompassed by standards and codes of practice for professional engineering

WP6: Involve collaboration across engineering disciplines, other fields, and/or diverse groups of stakeholders with widely varying needs

WP 7: Address high level problems with many components or sub-problems that may require a systems approach

WA 4 – Investigation (V4)

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

Drawing on WK8 - Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues

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Engineering New Zealand Criterion

The programme includes substantive, integrative project work (incorporating design or development of solutions) which is assessed against a range of overall programme graduate outcomes.

Programmes are also required to include sufficient individual research work to satisfy requirements for the award of an Honours degree. Integrative design and research components may be organised into separate courses or within a single course/project, which has distinct research and design elements, in which case the overall project is expected to be of at least 45 and ideally 60 credits in size.

Indicators of Attainment for WA3 Design

- Identifies all relevant constraints and requirements, including any need to partner with or co-develop with relevant Māori communities through the project.
- Identifies information requirements and selects what is relevant from the open literature.
- Demonstrates creativity when proposing possible solutions.
- Screens alternative solutions systematically.
- Applies modern design theories and methodologies to develop/design possible solutions.
- Evaluates the feasibility of several possible solutions in all relevant contexts which, as appropriate to the problem, may include: technical, sustainability, suitability for implementation, economic, aesthetic, ethical, health and safety, societal, environmental and cultural.
- Undertakes analysis to confirm the robustness of the proposed solution in the light of uncertain information and data.
- Describes the preferred solution and presents the findings in a coherent written form and defends those findings orally.

Indicators of Attainment for WA4 Investigation

- Reviews the open research literature.
- Identifies the needs for research or investigation.
- Identifies appropriate research or investigation methodologies.
- Designs and executes valid forms of research, experimentation or measurement.
- Calibrates/validates the data collection methods and equipment.
- Analyses the data including considering sources of error.
- Draws valid conclusions and justifies those conclusions.

Staffing Requirement for WA3 Design

Delivery of key design/capstone project courses involves staff members who are currently competent in engineering practice, e.g. as exemplified by recent success in a competence assessment.

Combined Project Approach

- 45 credit (0.375 FTE) – runs through both semesters
- Group design project (3 to 4 students ideal)
- As design proceeds, pause for research to obtain/measure missing data – ideally done and assessed individually
- Complete design as a group
- Group work assessment divides score using combination of peer and supervisor assessment
- Difficult to obtain suitable, but realistic projects
- Supervising staff require both design and research skills

Separate Project Approach

- 30 credit (0.25 FTE) research/investigation project running full year – done individually
- 15-30 credit (0.125-0.25 FTE) design project done in Semester 2 in groups of 3-4
- Research project can be supervised by wide range of academic staff
- Design project supervision restricted to those competent in engineering practice
- Design project selection less constrained – ideally shadow actual projects

“Spending” vs “Earning” Capstone Design Projects

Fundamental differences:

- Infrastructural projects focus on wise use of capital – goal is to achieve service requirements within constraints at lowest cost, whilst keeping ongoing cost in bounds

- Product design projects focus on making something that can be sold at a profit – goal is to create a valuable product through innovative engineering - sale price must exceed the manufacturing costs but capital still important

Two Examples:

- Re-design of a complex traffic roundabout system with multiple entry and exit points located in a city site with the aim of reducing congestion

- Commercial development of an on-farm dryer to reduce the water content of grain prior to on-farm storage – intended for use in a rural area with limited infrastructure availability

Roundabout System – some questions

Appropriate to use a traffic modelling software to evaluate the effect of different re-designs on vehicle travel times, but what are wider considerations:

- Priority routes?
- Pedestrians?
- Parking/access to nearby businesses/residences/leisure facilities e.g. parks?
- Noise and air pollution?
- Time of day or time of week differences in travel patterns?
- Access for emergency vehicles?
- Weather impacts e.g. storm water, shade for pedestrians
- Constructability? Disruption and safety during construction?

Roundabout System – some questions:

- How widely should the system be defined:
  - Travellers may change their wider route, thereby invalidating the analysis
- What are the regulatory requirements to be met?
- How will local needs of the roundabout by businesses, pedestrians etc. be established?
- How lateral can solutions be within budget envelope e.g. overpasses or underpasses for through traffic? Pedestrian under or overpasses? Machine vision to control traffic light phasing?
- How will locals contribute to design brainstorming and screening of design concepts?

Grain Dryer System – some questions:

- What is known about the various locations the dryer might be used, and what infrastructural service is available in those locations e.g. access to power, telecomms, water, waste treatment? What capacity is available?
- What are the regulatory requirements?
- What is the likely ability of the dryer operator and what operator training is likely to occur in practice?
- What is the reliability of the power supply etc.?
- What are likely cleaning requirements?
- What level of fail-safe is required to ensure operator safety e.g. if there is a jam?
- Are there any environmental considerations e.g. noise, dust?

Grain Dryer System – some questions:

- Should only batch operation be considered?
- How variable is the entering raw material?
- Who are key stakeholders to work with to establish requirements and contraints, and to involve in conceptual development of possible solutions?
- What are likely maintenance needs, and who might do these?
- Does energy efficiency matter? Sustainability more generally?
- Does the dryer need to be portable? If so, by what means e.g. a permanent mount on a trailer?
- Manufacturability? Value of standardisation of componentry?
- What is the affordable price envelope? Can the dryer be sold profitably?

Implications for supervision

- Supervisor needs confidence in the iterative design process that students will attempt
- Supervisor cannot predict in advance all important factors so must be adaptable to let the project go where stakeholders and students wish to take it
- Managing project boundaries is vital to keep the project and total student work load to a reasonable size
- There needs to be a means for resolving how to move forward when critical information is missing or delayed – requirements and constraints can be re-set, but in a managed way

Revisiting Indicators of Attainment for WA3 Design

- Identifies all relevant constraints and requirements, including any need to partner with or co-develop with relevant Māori communities through the project.
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- Demonstrates creativity when proposing possible solutions.
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Supervision and Assessment

- Capstone projects are also critical to peak assessment of other graduate attributes:
  - WA 6 The Engineer and The World
  - WA 7 Ethics
  - WA 8 Individual and collaborative team work
  - WA 9 Communication
  - WA 10 Project Management and Finance

- Establish an assessment rubric based on learning outcomes – this should reflect TABEE indicators of attainment for relevant graduate attributes and your own programme outcomes

- Establish a supervision model accordingly e.g.

Supervision and Assessment (cont.)

- Rotating team leadership, with regular observation of meetings
- Requiring teams to develop and run their project to a pre-prepared project management plan
- Other staff role-playing if real stakeholders are not available
- Challenging the students should an ethical dilemma arise
- Giving report examples, but avoiding rigid report templates – deciding how to organise a report is an important part of learning
- Requiring each student to present verbally, and identify their own written contribution
- Using open peer assessment of other group members – all sign their agreement to consensus allocation
- Providing appropriate space/resources available out of hours for teams to work together

In Summary

- There is no one model for a successful capstone – Thailand needs to identify the sorts of models that work in its own context

- Clarity on suitable indicators of attainment for WA3 Design/ Development and WA4 Research/Investigation helps choose the most appropriate form of the capstone project

- Advice from Industry Advisory Committees can assist to define the capstone project model – from such advice regional universities might choose a different model to those in major cities

In Summary (cont.)

- Design capstone projects demand different staff skills to final year research projects for successful supervision and assessment
- The difference between “spending” and “earning” design challenges needs to be accommodated
- Appropriate capstone-designated space where students can work collaboratively with resources at hand is a key success factor
- Success is best achieved when the students and the staff really have fun!