 THE UNIVERSITY of EDINBURGH
School of Engineering www.eng.ed.ac.uk

Experiments in Learning Design

Making space for **creativity** and continuity in design **education**

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School of Engineering



 THE UNIVERSITY of EDINBURGH
School of Engineering

Why change? Why now?


Creating Space for Creativity

Fostering Design Learning:

- Short projects
- Self-led and guided learning





 THE UNIVERSITY of EDINBURGH
School of Engineering

Four taught disciplines:

Chemical Engineering	Civil and Environmental Engineering	Electronics and Electrical Engineering	Mechanical Engineering
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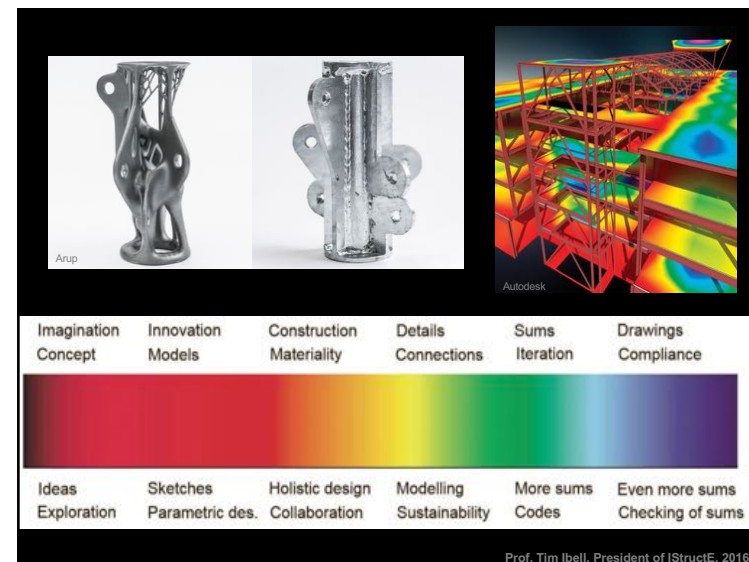
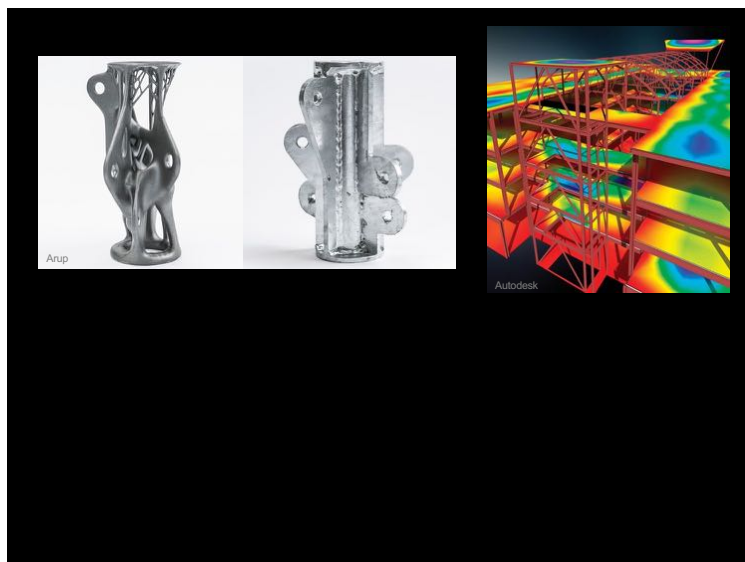
Three degrees in C&EE (about 90 students/year):

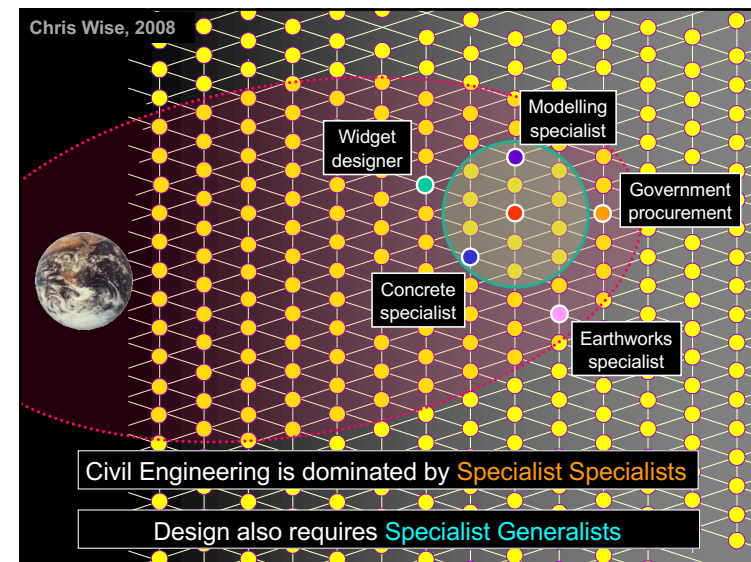
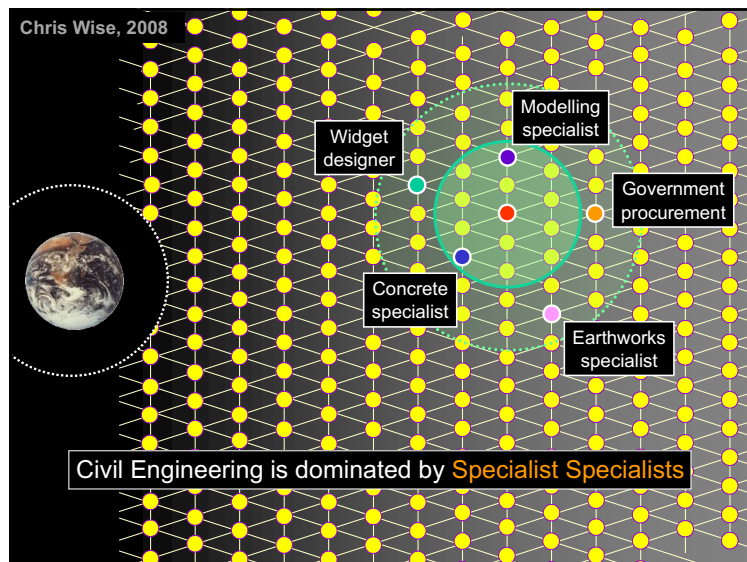
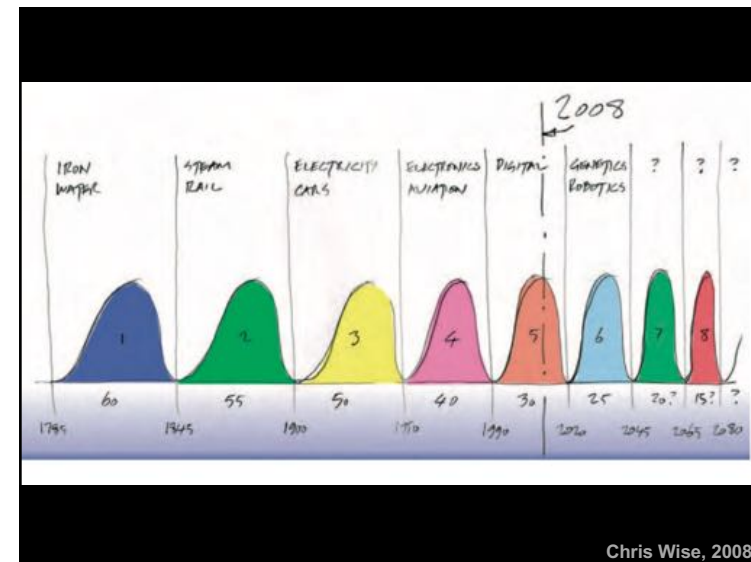
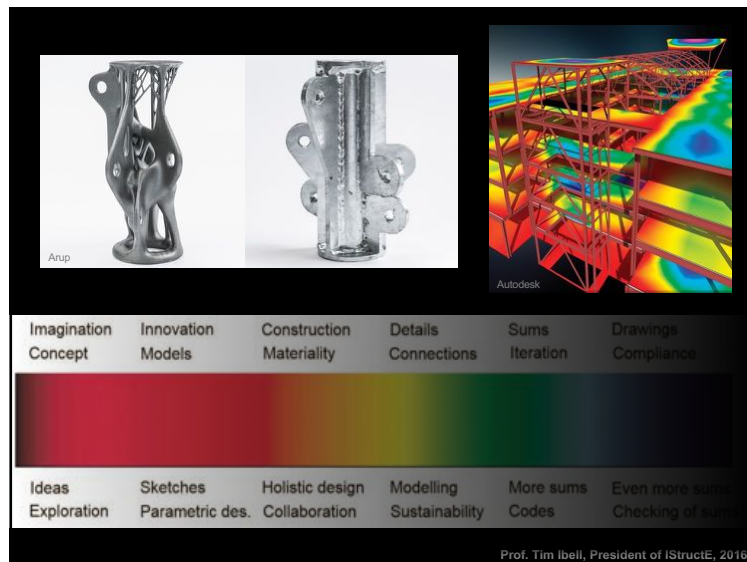
Civil Engineering	Structural Engineering with Architecture	Structural and Fire Safety Engineering
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As either:

- 4 year Bachelors of Engineering (BEng)
- 5 year Masters of Engineering (MEng)









How were we teaching "design" in 2008?

"Design" Courses in 2008

- 1 Civil Engineering 1
Hydropower project
- 2 Behaviour and Design of Structures 2
Code design of steel and concrete
- 3 Detailed Design of Structures 3
Code design of steel and concrete buildings
- 4 Civil Engineering Design Project 4
Tunnel design
- 5 Structural Engineering Design Project 5
Bridge Design

Interdisciplinary
Design Projects 4
(cross-Engineering)

Behaviour and Design of Structures 3
Concrete - Tutorial 1
Flexural Design of Beam Sections

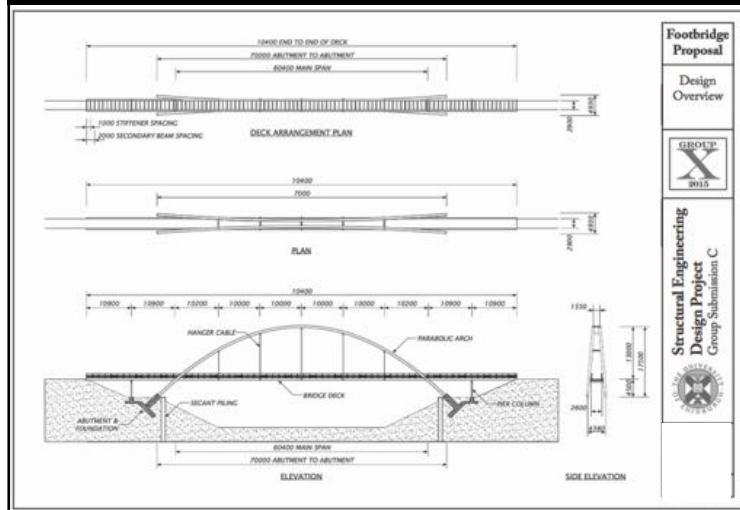
1. For each of the singly-reinforced concrete beam sections shown in Figure 1:

- determine the depth of the neutral axis;
- check that the beam is under-reinforced; and
- calculate the ultimate moment of resistance.

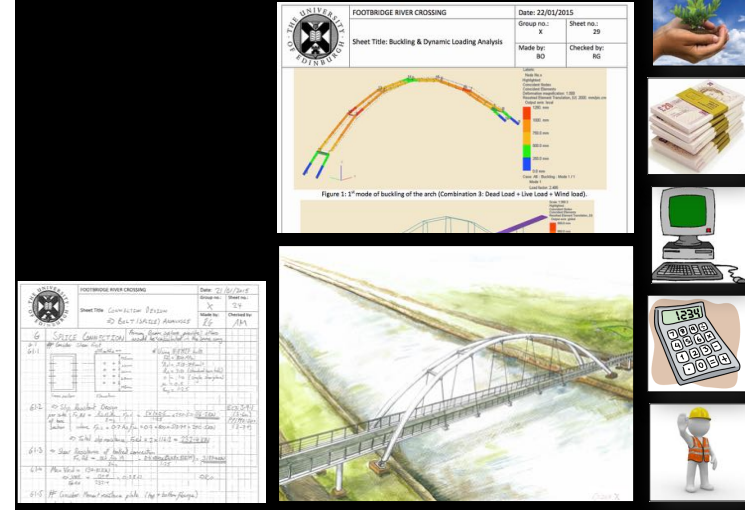
(a) (b) (c)

Figure 1 shows three beam cross-sections with their dimensions and reinforcement details. Section (a) is a rectangular beam with dimensions 350 mm x 250 mm, reinforcement 3-H16, and concrete strength C25/30. Section (b) is a rectangular beam with dimensions 280 mm x 220 mm, reinforcement 2-H12 and 2-H16, and concrete strength C30/37. Section (c) is a rectangular beam with dimensions 310 mm x 300 mm, reinforcement 4-x25 with $f_y=525\text{MPa}$, and concrete strength C70/85.

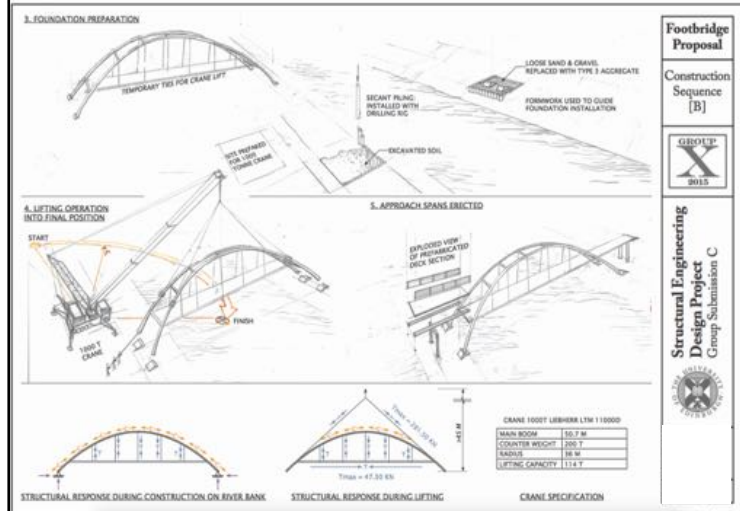
Group Design Projects



Group Design Projects



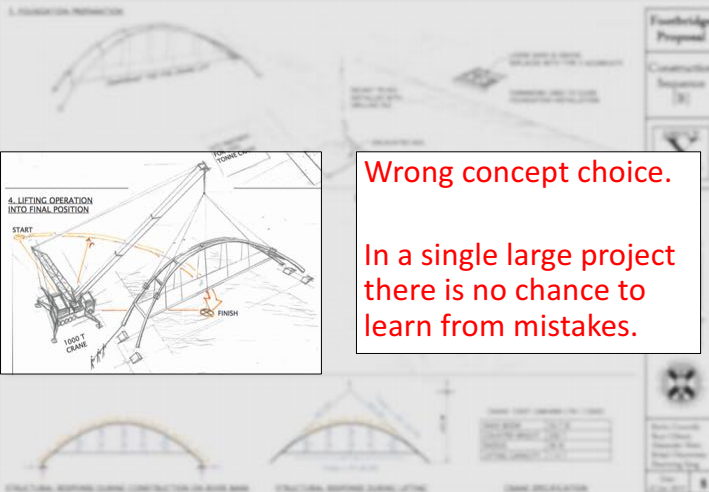
Group Design Projects



Group Design Projects



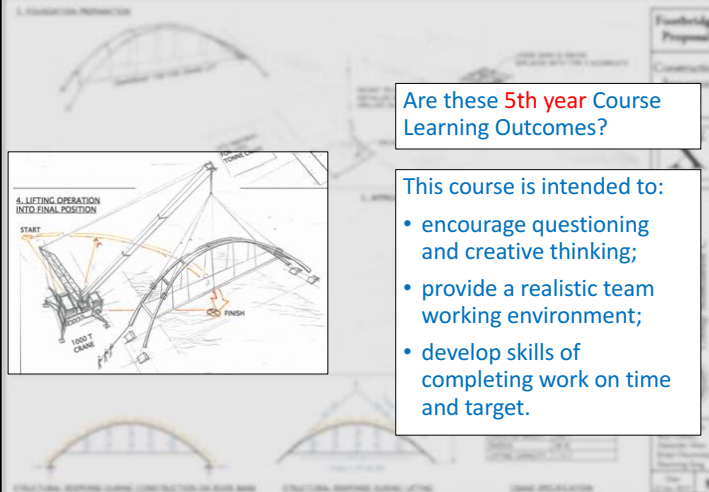
Group Design Projects



Wrong concept choice.

In a single large project there is no chance to learn from mistakes.

Group Design Projects



Are these 5th year Course Learning Outcomes?

This course is intended to:

- encourage questioning and creative thinking;
- provide a realistic team working environment;
- develop skills of completing work on time and target.

Creativity and Continuity

“ Civil Engineering is the art of directing the great sources of Power in Nature for the use and convenience of man;

being that practical application of the most important principles of natural Philosophy which has in a considerable degree realized the anticipations of Bacon, and changed the aspect and state of affairs in the whole world. The most important object of Civil Engineering is to improve the means of production and of traffic in states, both for external and internal Trade. This applied in the construction and management of Roads - Bridges - Rail Roads - Aqueducts - Canals - river navigation - Docks, and storehouses for the convenience of internal intercourse and exchange; - and in the construction of Ports - Harbours - Moles - Breakwaters - and Lighthouses, and in the navigation by artificial Power for the purposes of commerce.

Thomas Tredgold
Institution of Civil Engineers, Royal Charter, 1828

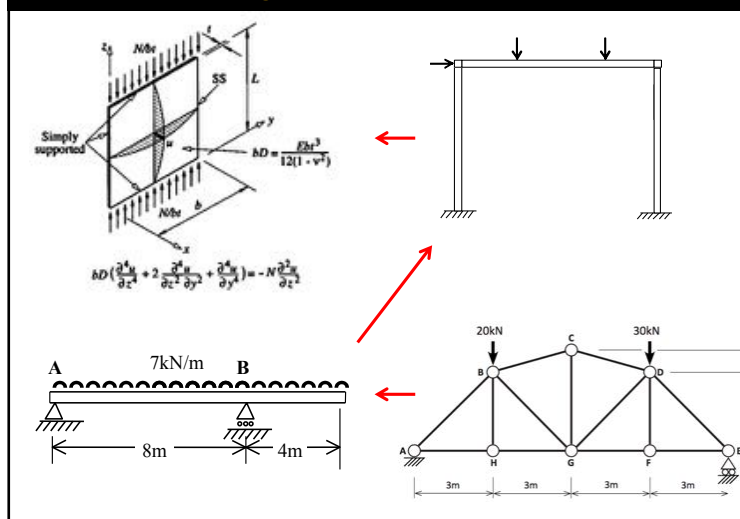
“Engineering problems are under-defined, there are many solutions, good, bad and indifferent. The art is to arrive at a good solution. This is a creative activity, involving imagination, intuition and deliberate choice.”

Ove Arup

“Engineering is the art of modelling materials we do not wholly understand, into shapes we cannot precisely analyse so as to withstand forces we cannot properly assess, in such a way that the public has no reason to suspect the extent of our ignorance.”

Dr A R Dykes (IStructE, 1976)

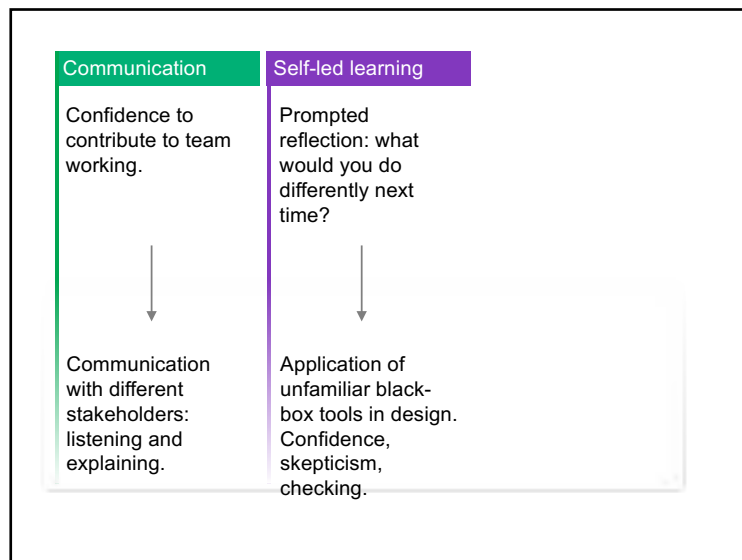
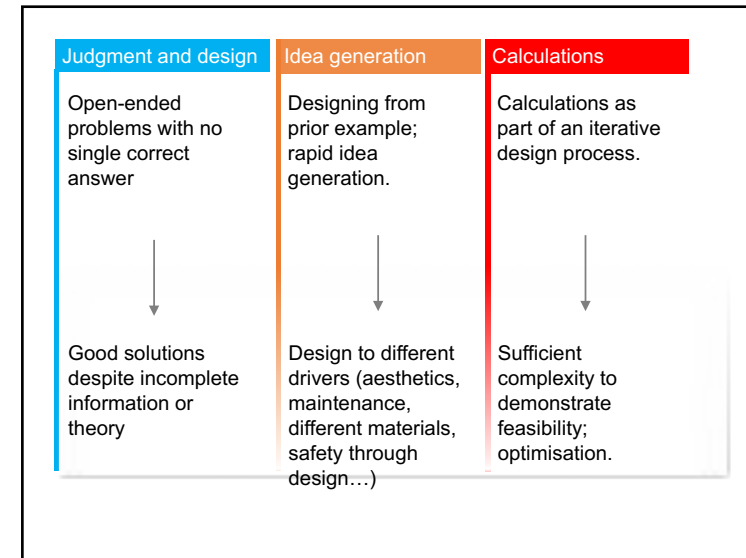
A Structures Learning Thread



Creating a Design Learning Thread

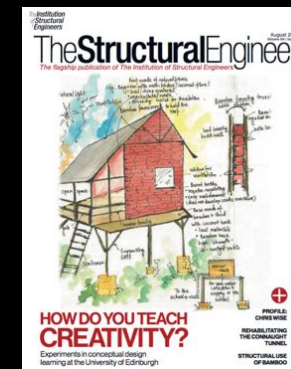
Civil Engineering 1	4 x pm 6 x pm	Road design; bridge inspection Hydropower reservoir
Tools for Engineering Design 2	1 x pm 2 x pm 2 x pm 3 x pm 3 x pm	1 minute designs; 15 minute designs KB engineering estate upgrade Education masterplans in Africa Design-build-test Calculation, drawing, reflection tasks
Conceptual Design for Civil Engineers 3	1 x pm 1 x pm 2 x pm 5 x pm	Timber design initial concepts Restaurant cantilevered off cliff face Cable car over dockyard TRADA Timber design project
Interdisciplinary design project 4	10 x pm	Passive house / potable water / hydropower
Civil Eng Des Proj 4	2 wks full time	Geotechnical design (immersed tube tunnel; wind turbine foundations). Transportation design
Structural Des Proj 5	2 wks full time	Bridge design

	Judgement and design	Idea generation	Calculations	Communication	Self-led learning
1st year					
Civil Engineering 1 - Bridge inspection + Road design (4x2h) - Hydropower design (6x2h)	Open-ended problems with no single 'correct' answer	Tackle design problems that are well defined.	Calculation as part of a design process that requires trial and error and judgement. Spreadsheets for design iteration.	Exploiting teams: time management, group dynamic, individual skills	
2nd year					
Tools for Engineering Design 2 - Games (Pictionary, ready-steady-design, Countdown) (1x3h) - 15 minute design problems (1x3h) - Upgrade of a water supply network (2x3h) - Design-communicate-build-test-learn (3x3h) - Calculation, drawing, reflection tasks (3x3h) - Self-study tasks (AutoCAD, drawings, Excel)	Interpreting a brief: Uncertainty in the brief; conflicting demands. Judgement, compromise, choice.	Rapid idea generation (1 minute designs) Designing from prior example - Targeted internet use. - Critical application of previous projects to solve a brief. - Appreciation of solutions and proportions that 'look right'.		Critique, evaluation and discussion skills. Confidence to contribute to discussions. Drawing for different purposes: - sketching in design, - technical drawings, - visualisations. Stakeholders (client, contractor, regulatory body, user, neighbour, activist...) - Gathering and understanding stakeholder ideas and opinions - Explaining designs to different stakeholders.	Prompted reflection after each project. What would you do differently next time? Portfolio. With self-led reflection exercises consolidating learning at end of each course. Building a personal library of experience: - the internet, - 'coffee-table' books, journals, The Structural Engineer, ... - Site visits - History and case studies.
Detailed Design 2 (steel and concrete sectional design, with detailed design tasks).					
3rd year					
Conceptual Design for Civil Eng 3 - TRADA timber design: initial concepts (1x3h) - Restaurant cantilevered off cliff face (1x3h) - Cable car over a dockyard (2x3h) - TRADA timber design, themed sessions on materials, construction, connection detail concepts (5x3h)	The importance of getting the concept right (cost of change increases as the project progresses). Producing good solutions despite incomplete theory or information.	Designing to different drivers (aesthetics, costs, buildability, maintenance, cradle-to-grave, ...). Essential vs. desirable drivers. Different designs based on materials available: - Steel, concrete, glass; - Masonry and timber; - Straw, plastic bottles, shipping containers. Safety through design (CDM). Examining hazards from the outset of the design process.	Calculations of sufficient complexity to demonstrate feasibility and explore ideas. (Span: depths ratios...) Optimisation: criteria, calculations, judgement, subjectivity.	Communication to avoid confusion - Complete, concise, clear. - Meetings, keeping notes. - Discussing designs via video conference. - Written, drawn, verbal communication.	Confidence and ability to learn and apply new tools and unfamiliar design methods. (e.g. timber design without teaching timber). Application of unfamiliar black-box tools in design. (e.g. computer tools). Confidence, scepticism, checking.
Structural Form, Function and Design Philosophy 3 (exploration of structural forms, materials, loads, load paths, design theorems)					
Engineering Sustainability 3					
Detailed Design 3 (code design of steel and concrete structures, including detailed design tasks).					
Civil Engineering Construction 3					
4th and 5th years					
Interdisciplinary design project 4 (10x3h) Passive house / Potable water / Hydropower (with chemical, mechanical, electrical engs.)	Reinforcement and practice on design tasks of increasing depth and complexity		Choice and application of a range of detailed design calculations.		
Civil Eng Design Project 4 (2 wks full time) Geotechnical and transportation design.			Choice and application of computer analysis methods.		
Bridge Design Project 5 (2 wks full time)					

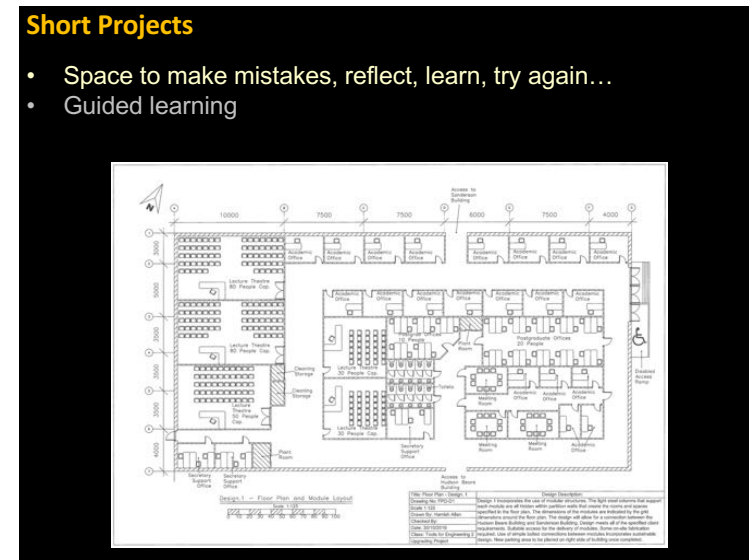
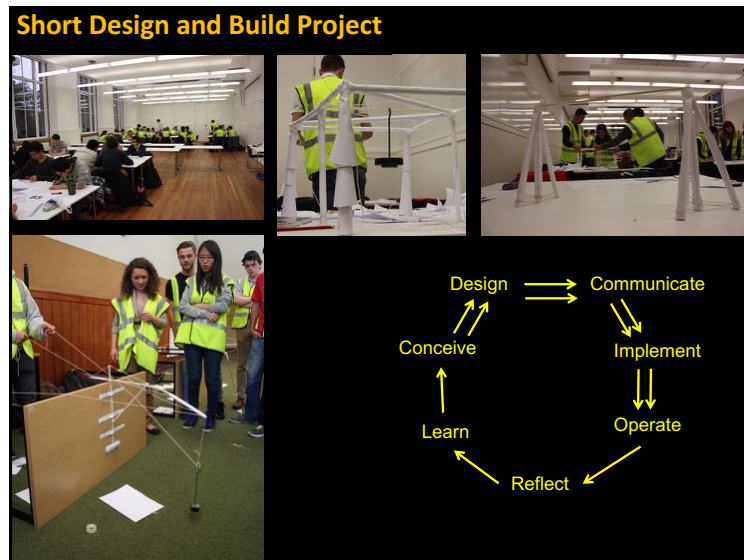
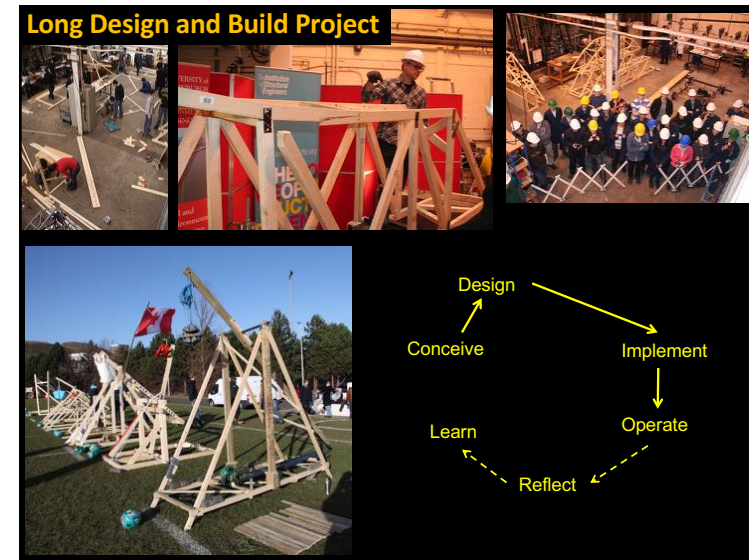


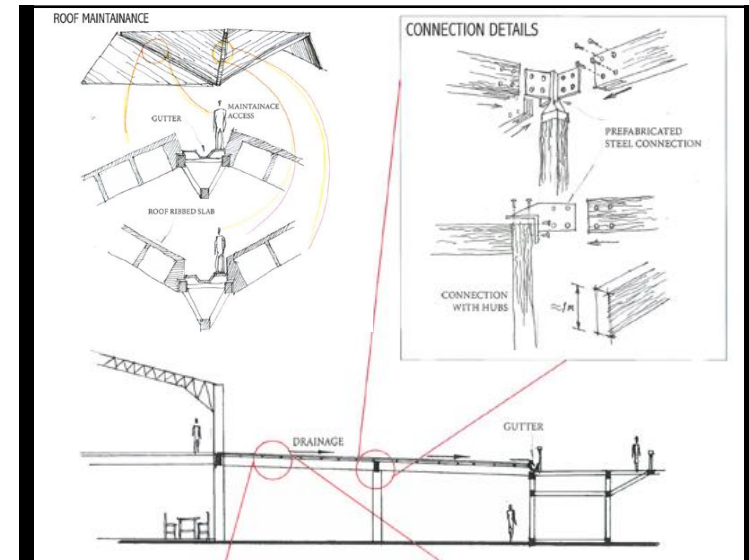
Space in 1st to 5th year to ...

- **nurture** design ability;
- experiment, **make mistakes**, learn, build confidence; and
- ability to **learn and apply new tools** for yourselves, in a skeptical, self-critical way.



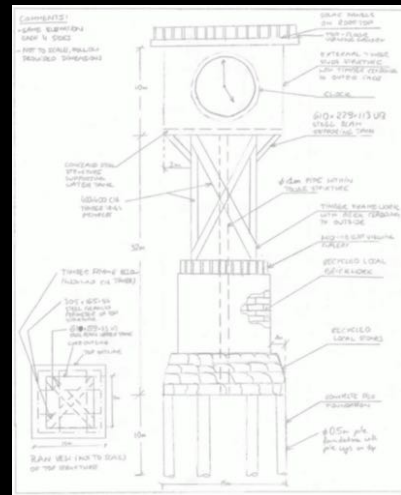
And... design gives the **context and motivation** for learning technical **analytical methods**.



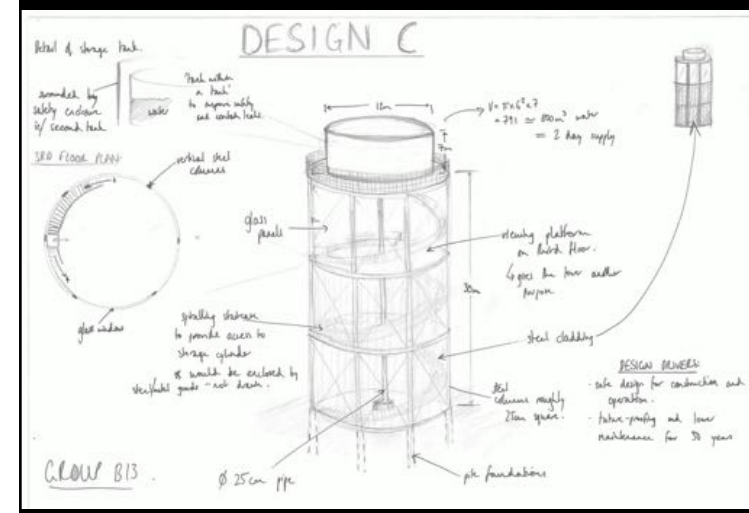


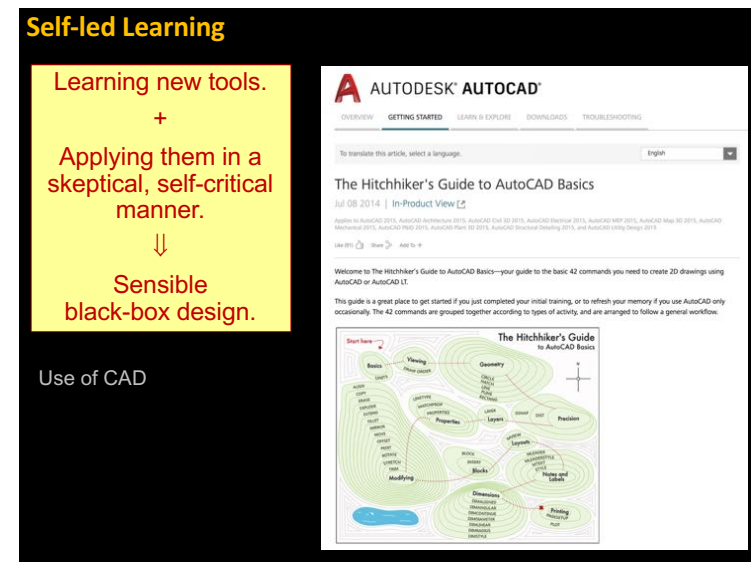
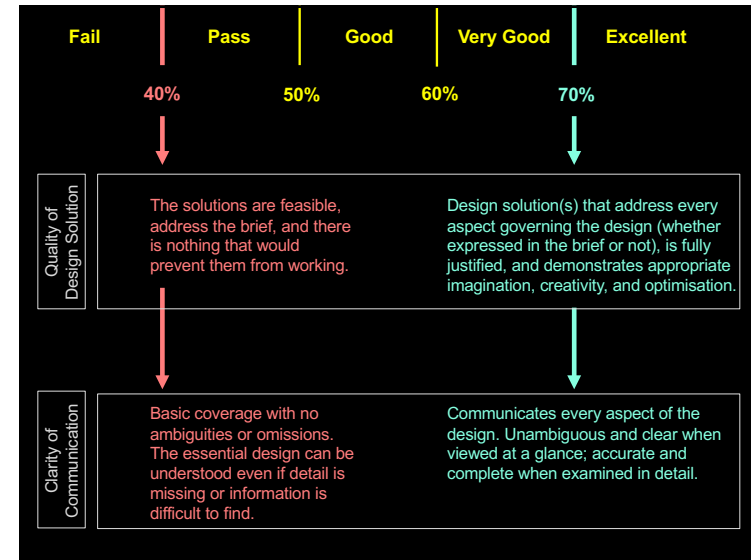
Design Drivers

Groups		Driver
B1	B6	Future-proof and maintenance free for 50 years
B2	B7	B10 A transparent landmark structure
B3	B8	B11 Carbon-neutral construction and operation
B4	B9	B12 Minimise the whole-life cost of the project
B5		B13 Prioritise safety during construction, operation, and de-construction at the end of life.



Design Drivers





Self-led Learning

Learning new tools.

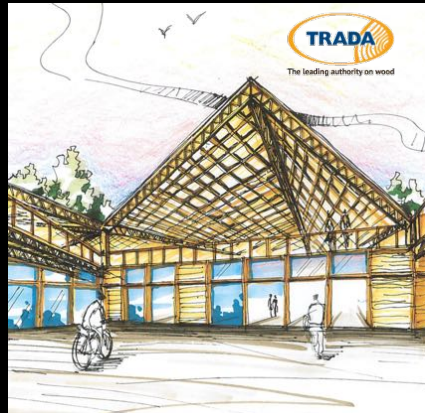
+

Applying them in a
skeptical, self-critical
manner.

↓

Sensible
black-box design.

Drawing skills



Self-led Learning

Learning new tools.

+

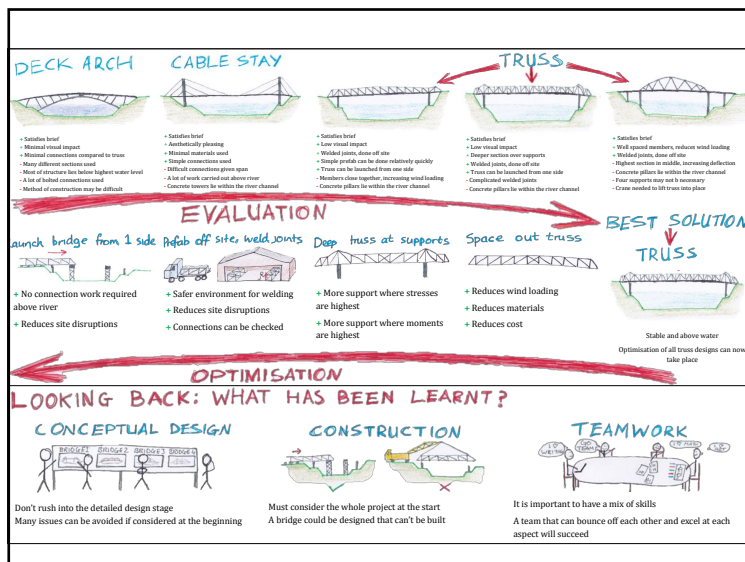
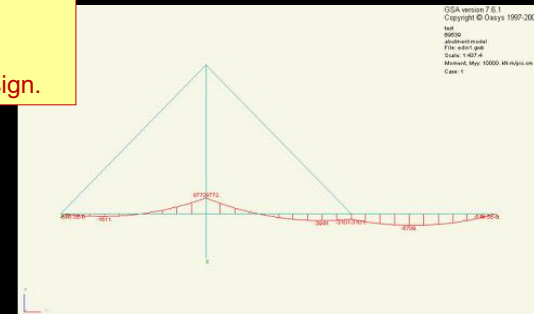
Applying them in a
skeptical, self-critical
manner.

↓

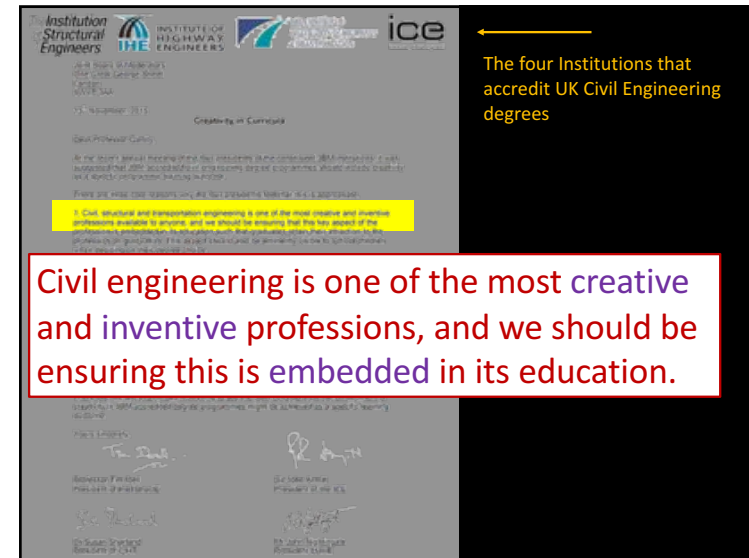
Sensible
black-box design.

Analysis software

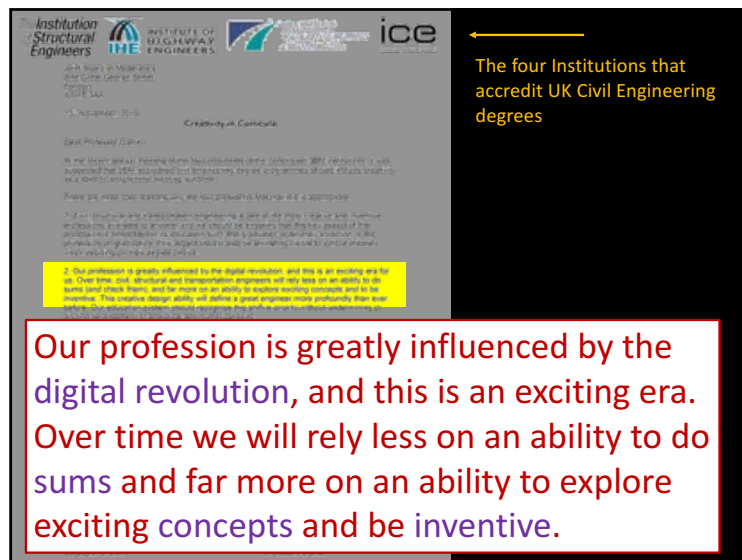
... without being
taught the theory



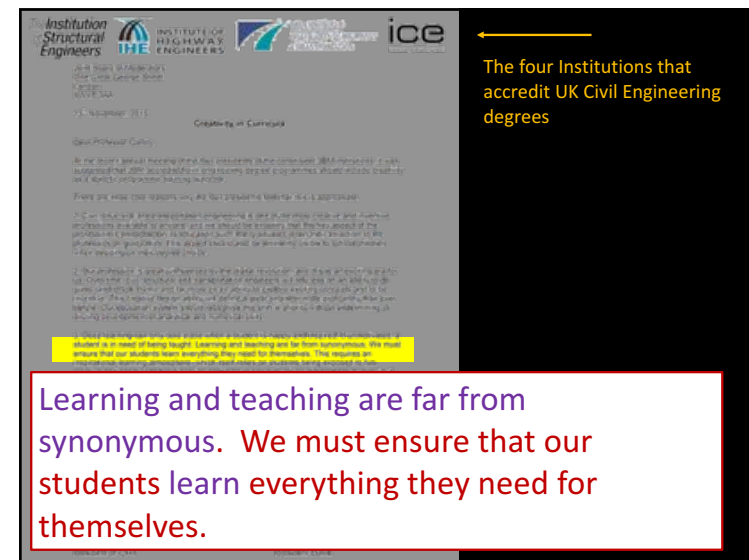
Summary



Civil engineering is one of the most creative and inventive professions, and we should be ensuring this is embedded in its education.



Our profession is greatly influenced by the digital revolution, and this is an exciting era. Over time we will rely less on an ability to do sums and far more on an ability to explore exciting concepts and be inventive.



Learning and teaching are far from synonymous. We must ensure that our students learn everything they need for themselves.

With particular thanks to:

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