What should be taught in undergraduate Civil Engineering courses? Comprehension, Inspiration and Invention

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1) Introduction: Slides 1,2,3

Engineering is essential to sustaining our existence – our need for wise and creative application of science and technology has never been greater. The future of construction engineering lies with us being creative solvers of the big problems that affect our clients, our society and our planet. To do this we need to have holistic solutions to their problems. This requires an ability to think beyond the traditional discipline silos and work together creatively.

We need to find ways to create engineers who have a broader comprehension of the built environment, and, to maintain commercial advantage, we need people who can keep us ahead of our global competitors.

In the simplest terms, I believe that engineering education should encourage:
1) Basic technical understanding – the COMPREHENSION of the physical laws
2) Curiosity, motivation, passion – INSPIRATION
3) Ability to drive the process of design and creativity- INVENTION

2) What does good look like?

It is important that industry and the professions make it clear what they are looking for. What does good look like?

From my perspective it would say a good Graduate Engineer is:

1) Well founded

Well founded in fundamental principles of mathematics and science and able to develop new engineering skills from a solid base. Having the confidence to go beyond codes and regulations and not be bound by rules and codes. Able, when needed, to extrapolate knowledge into new territory.

2) Inspired

Inspired by the world; the world at home, at school, college and work. Inspired to seek out knowledge and experience and, of course, inspired to build a career in engineering

3) Collaborative

Able to work at the interfaces between traditional skill sets, disciplines and curious about what is beyond their borders; Able to innovate into new territory; Able to communicate – an essential attribute to collaboration. Having “multi-

cultural instincts" and being able to work with people of different cultures successfully.

4) Adaptable

Able to develop to suit changing markets; Able to adapt to new technologies; Able to stay relevant for a whole career; Able to adapt to international requirements

5) Varied

There is no doubt that we need a variety of engineers for a successful profession. We need people who can conceive new ideas. People who can work out what the problems are before they need to be solved. We will also need people who can work at the detailed level and develop new technical solutions to problems.
We also need a variety of educational opportunities so that these people can come to the fore. We would be wrong to think that there is a single right way. But we do need to be more mindful of what it is that we need to be developing through education so that we have a fair chance of getting wit we need.

3) How should we teach? Slides 4,5

We all start off fascinated by what's around us. We all start with an urge to create. It is a matter of nurturing the fascination that comes so early, harnessing the urge to be creative and to make something new. This can be so easily stifled at an early age.

Are we putting young people where we can control them but where they cannot grow and flourish as we really need? How do we harness the creative forces of the young and make them our future? How do we teach our engineers to create? Creativity is the driving force of our survival, so how do we stop killing our children's fascination and creativity?

Creativity needs things to fuel it into making ideas, and things to make it yield value and results:

1) curiosity/motivation/purpose/reason: Drivers
2) ideas/hypotheses/dreams: Concepts
3) knowledge/experience/experiment/analysis/precedent: Scheme
4) Appraisal/choices/assessment: Analysis
5) End result/conclusion: Design

We can apply these stages to any problem. But in teaching it is too easy to focus on the analytical part. Admittedly this is the part that needs the most detailed understanding of the world of materials, physics and modelling. It is the part that demands the most research. But in a university where research dominates then the natural focus is to teach the detail and forget the rest. So we kill engineering as a creative art/science and turn it into a set of disconnected theories about the world that it is hard to apply with any clarity or inspiration.

So how do you teach and encourage every level of the process? How do you stimulate curiosity, stimulate ideas, enable people to apply knowledge and appraise ideas and then select solutions through good judgement? In short how do you teach the creative

process? And how do you encourage cross-pollination to make something new come from some things already known?

I am confident that we can do a lot to teach creativity – it doesn't have to be the province of the "arty" or the slightly crazy. We can teach creativity by showing that there is a process you can go through that gets you to something original; something that is of your own making. It's like in practice where design follows a series of steps. And we can give children and students hands on experience.

4) Who is responsible for teaching engineers? (Slide 6)

It is worth looking at the interfaces between teaching, practice and research. We operate with too great a distinction between the three. As is the case so often, the most interesting things happen where you work across conventional boundaries and this is true for education.

We need more engineers from practice in teaching; more professors from universities to be involved in practice; more research to be done within practice in collaboration with academia.
Partnerships between practice/business and academia are essential. We need to fuzz the boundaries more and more.
At university we need Heads of Departments who recognise the value of design as well as the more measurable and academic subjects. And we need the "Quality Indices" to have the flexibility to consider and measure the quality of teaching in engineering so that there is incentive to ensure that standards are raised.

In short, responsibility for the creation of our engineers should not fall only on the shoulders of the universities. We need to go beyond the silos of academia, practice and research and work together on getting the best engineers we can.

5) Teaching Creativity to Engineers (Slides 7 to 13)

Under Prof David Nethercot, Head of Department of Civil and Environmental Engineering at Imperial College, I have been able to turn my hand to teaching as Adjunct Professor of Creative Design for the past two years. Creative Design is an integral and compulsory element within the Civil Engineering course for all first and second year students and leads to further, more detailed design project work in their third year.

The aims that I have set for the course and have agreed with Imperial College are:

- To inspire the students to want to study to become creative engineers
- To teach the students the essentials of creative design in the context of their engineering course work
- To allow the students to experience collaborative, creative design engineering working in teams through project work

We are trying to show the students that everyone can be creative – it is a matter of understanding the stages of thought, allowing freedom of imagination without censor and only focussing on detail at the right time.

An important aspect of the course is that the majority of presentations, every day, are given by young practicing engineer who speak of their experience in developing from graduates to valued engineers with exciting careers. Following the presentations the students move to the "studio" space and work together in groups of 8 or 9 students.

The students' work is assessed informally at the end of the day through "progress boards" and formally assessed at the end of each week through team presentations of their work to a group of "assessors" from industry.

The design projects are set to allow the students to experience the development of a project from conception to detail design. The project briefs are designed to encompass a wide spectrum of engineering from urban planning, master-planning, large-scale building design, and small-scale component design. They require students to consider a wide range of engineering aspects including: commercial drivers, planning issues, social impact, environmental impact, energy and waste, transportation, carbon footprint, structural integrity, buildability, construction, health and safety, maintenance, aesthetic quality (and value). They are introduced to these concepts through the morning presentations and tested through the application to their project work during that week. They are required to undertake considerable research and self learning to be able to report on the more detailed engineering aspects.

In their third year, students engage in a Group Design Project which runs over five weeks and provides an opportunity for students to bring together all they have learnt about the technology of engineering, the practice of creative design, and the management of group activity. The five weeks of "Creative Design" that they have experienced in years one and two gives them some of the creative and collaborative skills that will help them in this more focussed and detailed design project. Each year builds up their experience and capability.

7) Conclusion (Slide 14)

So in conclusion I think we need:

1) Universities that encourage teaching and that recognise the bigger picture – and encourage cross-departmental working
2) Courses that seek to create holistic thinkers; creative engineers
3) A better linked up professional network for engineering that sees teaching as their responsibility too
4) Government that recognises that creating good engineers is crucial to our future and that universities need to be funded for teaching excellence not just research excellence