GeoEngineering Education

1. What should graduates be able to do?
2. What and 3. How to teach to enable them to do it?

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Cino Viggiani, Grenoble (France)
## What should graduates be able to do?

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<tr>
<td><strong>MAIN TOPICS</strong></td>
<td><strong>TASKS RELATED TO MAIN TOPICS</strong></td>
<td><strong>MAIN TASKS</strong></td>
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<tr>
<td>2. Material Behavior and Properties</td>
<td>Estimate $\varphi$ and $S_u$ from soil descriptions</td>
<td>• Describe soil, determine $L_I$, $D_R$, estimate parameters ($\varphi$, $c$), $S_u$, Strength-State, $E_0$($S_u$)</td>
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<td>Sandcastle experiments, determine $u$</td>
<td><strong>EVALUATE DESIGN PARAMETERS</strong></td>
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<td>3. Investigations and Modeling</td>
<td>Describe soil and rock in engineering terms</td>
<td>• Create a 3D geotechnical model = materials + locations in 3D + engineering properties = strength, stiffness, drainage</td>
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<td>4. Groundwater</td>
<td>Draw flownet, calculate flow rate and $U$</td>
<td>• Construct flownet for steady-state seepage</td>
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<td>5. Slopes and walls</td>
<td>Calculate limiting undrained slope height and limiting drained slope angle</td>
<td>• Design a safe slope, use critical state friction angle (Slide 54)</td>
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<td>Analyze slope stability in jointed rock</td>
<td>• Analyze rock slope</td>
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<td>Calculate stability of retaining walls</td>
<td>• Calculate limiting active and passive pressures on walls using critical state strength</td>
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<td>6. Foundations</td>
<td>Calculate bearing capacity &amp; settlements of simple shallow foundations</td>
<td>• Design foundation using bearing capacity concepts or elasticity theory, calculate amount and time for settlement</td>
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<td>Calculate capacity of a single pile</td>
<td><strong>MODEL THE GROUND</strong></td>
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<td>7. Earthworks and materials</td>
<td>Determine compaction curve</td>
<td><strong>DESIGN SIMPLE SLOPE AND FOUNDATIONS</strong></td>
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The geotechnical graduate should be able to

- Follow design methods given in textbooks.
- Carry out computer-based calculations, with a little guidance:
  - Spreadsheets, Slope stability, Finite elements
- Read geological maps and memoirs.
- With some assistance, plan a ground investigation, describe the materials, specify testing and report the results.
- Write reports of ground investigations and designs, and present results in person.
- Know his/her limits, but expect to expand them and/or to find others who have complementary skills.

Brian Simpson – USA/UK IW on Education, Cambridge, September 2014
The question "What should graduates be able to do?" is I believe the wrong question. It encourages a "formula" or cook-book approach to the subject, in fact a narrow theoretical approach.

I think the question should be along the lines:

What **understanding** should graduates have that will enable them **to become** good geotechnical engineers?

*Laurie Wesley, written contribution to this workshop*
In geotechnical engineering the design process can be considered (somewhat simplistically) to consist of the following steps:

• Gathering basic information on soil conditions, that is, the geology of the site and the soil stratigraphy.

• Carrying out appropriate tests, in the field, or in the laboratory, to determine soil properties, particularly parameters needed for design computations.

• Carrying out an analysis by using the relevant parameters in an appropriate theoretical "model", which could be a bearing capacity formula, a slip circle calculation, or a sophisticated numerical model.

We should appreciate that soil mechanics and geotechnical engineering are distinctly different. The first provides a theoretical basis, and the second is a practical undertaking that makes use of this basis and the other aspects listed above.

I don't think it is possible for universities to teach geotechnical engineering (...) Universities should concentrate on teaching soil mechanics.
I cannot remember who told me once that to a young faculty who was asking to Professor Schofield what should he teach in a soil mechanics class (it was the first time he was), Professor Schofield answered: teach mechanics!

Nicht ist so praktisch wie eine gute theorie!

(Immanuel Kant, 1793)

So, what should we teach (and how)?
The engineering graduate

• Needs a broad knowledge of a lot of disciplines.
• BUT must have studied at least one discipline in depth.
• It may not matter too much which discipline.
• Must understand that knowledge can go deep.
• Must understand that rigour is possible, and recognise when it is not being applied by others.
• These basic tenets can then be applied to whatever topic is relevant.
• “It can be understood –it’s not magic.”

this is our role as professors
Geomechanics IS NOT Geotechnical Engineering

Geomechanics = Mechanics of Geomaterials (soil, rock, ...) understanding both the physics and the associated mathematics, which form the basis of an engineering approach
Geomechanics IS NOT Geotechnical Engineering

three preliminary, (trivial yet) important remarks

1. while the FEM has been used in many fields of engineering practice for over 30 years, it is only recently that it has begun to be widely used for analyzing geotechnical problems. This is probably because there are many complex issues which are specific to geotechnical engineering and which have been resolved relatively recently

2. when properly used, this method can produce realistic results which are of value to practical soil engineering problems

3. a good analysis, which simulates real behavior, allows the engineer to understand problems better. While an important part of the design process, analysis only provides the engineer with a tool to quantify effects once material properties and loading conditions have been set
three remarks: short version

1. geotechnical engineering is complex. It is not because you’re using the FEM that it becomes simpler

2. the quality of a tool is important, yet the quality of a result also (mainly) depends on the user’s understanding of both the problem and the tool

3. the design process involves considerably more than analysis
what should we teach?

Geomechanics = Mechanics of Geomaterials (soil, rock, ...) understanding both the **physics** and the associated **mathematics**, which form the **basis** of an engineering approach

- geomaterials are multi-phase materials (effective stress, drained *vs.* undrained, ...)

1. geomaterials = soils but not only
2. mechanics is not (only) about scalar quantities
3. fundamentals *vs.* complexity
why do I say "geomaterials" rather than "soils"?

A general feature of this study is the unified treatment of the mechanical behaviour of sand, rock, and concrete. The difference between soil mechanics, concrete mechanics and rock mechanics basically lies in the application. Then the three disciplines diverge because of the dominant role of water in soils, the role of fissures and joints in rocks and the role of tension cracks and reinforcement in concrete.
soil, rock, concrete: which is which?
mechanical behavior $\rightarrow$ stress, strain, constitutive relations

\[ \varepsilon = \Delta L / L_0 \]
\[ \sigma = F / S \]
\[ \sigma = E \varepsilon \]
\[ \sigma = C \varepsilon \]

our students should be equipped with (basic) tensorial algebra, NOT because they will use it, but because without it they won’t understand that stress is not the same thing as pressure!

they should also be equipped with (basic) knowledge of inelastic theories, because irreversible deformation is the rule rather than the exception in our field (and the codes they will use do not use elastic theory)!
Civil / Geotechnical / Environmental Engineering

Petroleum Engineering

Bio-inspired Geotechnics

Nuclear Waste Disposal

new fields of applications → at the interface with other disciplines
Sky and water by M.C Escher

The birds and the fishes retain their separate identities away from the boundary between sky and water but, at the interface, they are indistinguishable.

we work – more and more frequently – at the interface between various disciplines

M → HM → THM → THCM → THCBM

COMPLEXITY
the best way of facing up to the challenge of complexity is to master the fundamentals
HOW to teach? (just one slide)

using modern tools – e.g., x-ray μ-tomography + image analysis techniques
HOW to teach? (just one point)

using modern tools – e.g., x-ray μ-tomography + image analysis techniques

flying into a sand specimen
... inspired by the very nice lecture by Prof. Peter Day

yet another question – which is not less crucial than the three questions we’re discussing today

most failures in geotechnical engineering are not due to a lack of knowledge but rather to the failure to apply the knowledge we have

how to transfer research knowledge into practice?
education is what remains after one has forgotten everything he learned in school

Albert Einstein, 1931