GeoEngineering Education:
What should graduates be able to do
&
What and How to teach to enable them to do it

Marina Pantazidou
TC306 workshop
19th ICSMGE
September 20, 2017
Initial focus of education literature*

*Shulman (1986)
Changing focus of education literature
Changing focus of engineering education literature
Alternative –complementary– ways to decide & describe content

• List of topics (usually textbook chapters, sections), usual information in course syllabi
  • Example: Soil Classification

• List of learning outcomes (what students should be able to do)
  • Example 1*: Classify a soil according to the Unified Soil Classification System (USCS)
  • Example 2*: Predict the engineering behavior of soils (relative to compressibility, strength, and hydraulic characteristics) based on classification results

• List of key principles and concepts
  • No comprehensive list yet (true?)

*Fiegel (2013)
Meet our panelists!

Professor **Gye-Chun Cho**
Korea Advanced Institute of Science and Technology, Korea

Professor **Carlos Santamarina**
King Abdullah University of Science and Technology, Saudi Arabia

Professor **Cino Viggiani**
Université Grenoble Alpes, France
Panelists were invited to discuss:

(a) What all civil engineering graduates should be able to do within the domain of geotechnical engineering: let’s call it set $X$;

Inspiration for question (a): contributions to TC306 by Prof. John Atkinson (JA)

(b) **What to teach** so that graduates can do $X$;

(c) **How to teach** what we teach (specifically the fundamentals) so that graduates can do $X$ better,

after this introductory presentation, which they have seen in advance.
Workshop contents

• Setting the stage with this introduction
• Presentations by panelists
• Discussion on the topics of the workshop
• Wrapping up
Workshop contents & aims

• Setting the stage with this introduction
• Presentations by panelists
• Discussion on the topics of the workshop
• Wrapping up
  • Elements of a minimum set we can agree on?
  • Disagreements we cannot live with?
Introduction contents

• “What should graduates be able to do” according to Atkinson (2012, 2013, 2016)
  • Overview – comparisons – comments on “what & how to teach”
  • Advantages of JA’s approach
  • Disadvantage of JA’s approach

• “What to teach” according to Santamarina (2015) and Wesley (2015)
  • Personal selections & comments
## Graduate in civil engineering vs geotechnical engineer

<table>
<thead>
<tr>
<th></th>
<th>Atkinson 2012</th>
<th>Atkinson 2013</th>
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<tbody>
<tr>
<td><strong>MAIN TOPICS</strong></td>
<td>What a <strong>graduate in civil engineering</strong> should be able to do</td>
<td>What a geotechnical engineer should also be able to do</td>
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<tr>
<td>1. Basic Skills</td>
<td>Create spreadsheet calculations</td>
<td>Do routine insitu and laboratory tests and interpret results</td>
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<td>Write a technical report</td>
<td>Perform and validate numerical analyses</td>
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<tr>
<td>2. Material Behavior and Properties</td>
<td>Estimate ( \phi ) and ( Su ) from soil descriptions</td>
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<td></td>
<td>Sandcastle experiments, determine ( u )</td>
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<tr>
<td>3. Investigations and Modeling</td>
<td>Describe soil and rock in engineering terms</td>
<td>Create a geotechnical model including design parameters</td>
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<td>4. Groundwater</td>
<td>Draw flownet, calculate flow rate and ( U )</td>
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<tr>
<td>5. Slopes and walls</td>
<td>Calculate limiting undrained slope height</td>
<td>Design slopes and walls</td>
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<tr>
<td></td>
<td>and limiting drained slope angle</td>
<td></td>
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<td></td>
<td>Analyze slope stability in jointed rock</td>
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<tr>
<td></td>
<td>Calculate stability of retaining walls</td>
<td></td>
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<tr>
<td>6. Foundations</td>
<td>Calculate bearing capacity &amp; settlements of simple shallow foundations</td>
<td>Design simple foundations</td>
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<td>Calculate capacity of a single pile</td>
<td>Design an embankment on soft ground</td>
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<td></td>
<td>Design piled foundations</td>
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<tr>
<td>7. Earthworks and materials</td>
<td>Determine compaction curve</td>
<td>Design earthworks + pavements</td>
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Wesley (2012, 2015) disagrees on how (see slide 17)
Graduate in civil engineering & engineering geology

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<tbody>
<tr>
<td><strong>2. Material Behavior and Properties</strong></td>
<td><strong>Tasks Related to Main Topics</strong></td>
<td><strong>Main Tasks</strong></td>
</tr>
<tr>
<td>Estimate $\varphi$ and $Su$ from soil descriptions</td>
<td>Sandcastle experiments, determine $u$</td>
<td>Components of main tasks</td>
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<tr>
<td><strong>EVALUATE DESIGN PARAMETERS</strong></td>
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<td></td>
<td>Describe soil, determine $L_t$, $D_{rr}$, estimate parameters ($\varphi'$), $Su$, Strength-State, $E_0(Su)$</td>
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<td><strong>MODEL THE GROUND</strong></td>
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<td>Describe the geological history</td>
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<td>Create a 3D geotechnical model = materials+locations in 3D + engineering properties= strength, stiffness, drainage</td>
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<tr>
<td><strong>DESIGN SIMPLE SLOPE AND FOUNDATIONS</strong></td>
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<tr>
<td>Draw flownet, calculate flow rate and $U$</td>
<td>Construct flownet for steady-state seepage</td>
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<tr>
<td><strong>5. Slopes and walls</strong></td>
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<tr>
<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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<tr>
<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><strong>6. Foundations</strong></td>
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<tr>
<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>
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<td><strong>7. Earthworks and materials</strong></td>
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<td>Determine compaction curve</td>
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all/some/any in agreement?
“How to teach”: situate **big ideas** within big vistas (an example of how experts structure knowledge)

<table>
<thead>
<tr>
<th>Basis of geotechnical design</th>
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<tbody>
<tr>
<td><strong>Loading and drainage</strong></td>
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<tr>
<td>Drained (effective stress)</td>
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<td>Undrained (total stress)</td>
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<tr>
<td><strong>Calculation</strong></td>
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<tr>
<td>Plastic failure,</td>
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<tr>
<td>Elasticity</td>
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<tr>
<td><strong>Criterion for acceptance</strong></td>
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<tr>
<td>Factor of safety for ULS (typically 1.25),</td>
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<tr>
<td>Factor for SLS (typically 3) or load factor (typically $\frac{1}{3}$)</td>
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<tr>
<td>Movement (e.g. foundation settlement)</td>
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Atkinson (2016), Slide 52
Advantages of considering “What should civil engineering graduates be able to do” (Atkinson 2012, 2013, 2016)

• Emphasize what graduates should be able to demonstrably do
  • Transparency & accountability (requires suitable assessment)
  • Complete list (may agree or modify to produce alternate complete list)

• Include only the minimum set of geotechnical tasks for all civil engineering graduates
  • Focus on the core of geotechnical engineering (genuine core to later build upon, not simplified to later undo)

• Group geotechnical tasks in a few categories
  • Highlight importance of task categories (evaluate design parameters – model the ground – design simple slope and foundations)
  • Complete list (may agree or modify to produce alternate complete list)
Disadvantage of considering “What should civil engineering graduates be able to do” (Atkinson 2012, 2013, 2016): important point communicated by Wesley (2017)

• Emphasize methods at the expense of understanding?
  • Not necessarily, if understanding is articulated and assessed, but again, by observing things that students *do*
  • For example:
  • “Civil engineering graduates need to know when (or why) a total stress or an effective stress analysis is appropriate.” (Wesley, 2017)
  • What will count as evidence that graduates indeed know when is total or effective stress analysis appropriate?

**Challenge** for the (geotechnical) engineering education community: **How do we assess understanding?** (And other high-level objectives.) Problematic to depend mostly on problems requiring calculations.
Santamarina (2015) what to teach

NOT to teach: two examples

• Category: Misnomers
  • “Abandon cohesive soil, cohesionless soil” (Lambe*, Schofield*)
  • Burland (2012) agrees and suggests “clayey soil – granular soil”
  • Suggestion: Abandon cohesion as well?

• Category: Restrictive/simplistic tricks that are not sound
  • “UU tests, total stress analyses: are we not ready for a clean parting with total stress yet?”
  • Comment: To get ready, I need to see for the same problem, both types of analyses side-by-side

*In Appendix 1 of an earlier version of Santamarina (2015)
Wesley (2015) what to teach

• Use linear vertical strain/pressure curve
  • retire the semi-logarithmic e-log(p) curve, retire compression index $C_c$

• Retire theory that does not agree with evidence = calculations of maximum stable height of vertical clay banks yield large heights [for a typical firm to stiff soil]
  • Total stress analysis, upper bound: $H_c = 4S_u/\gamma$ [25m]
  • Effective stress analysis (presumably upper bound as well?): $H_c = 4c/\gamma (K_a)^{1/2}$ [7.2m]
  • Atkinson (2007) mentions a design value of $H_c = 3.8S_u/\gamma$ [~24m]
  • Total stress analysis, lower bound (Atkinson, 2007): $H_c = 2S_u/\gamma$ [12.5m]

Nagging question: if evidence gives heights lower than the lower bound, what is wrong with theory?
References

- Santamarina, J.C. 2015. (What) To teach or not to teach – that is the question, Geotechnical Research, 2:4:135-138, http://dx.doi.org/10.1680/jgere.15.00004
- Wesley, L. 2015. (What) To teach or not to teach – from theory to practice, Geotechnical Research, 2:4:139-147, http://dx.doi.org/10.1680/jgere.15.00005
- Wesley, L. 2017. Written contribution to the workshop, E-mailed July 6, 2017
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• Setting the stage with this introduction
• Presentations by panelists
• Discussion on the topics of the workshop
• Wrapping up
  • Elements of a minimum set we can agree on
    • Retire terms “cohesive/cohesionless soils”?
    • Retire e-log(p) curve?
  • Disagreements we cannot live with
    • Resolve failure of theory to predict max stable height of vertical clay banks?