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

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TC306 workshop

19th ICSMGE

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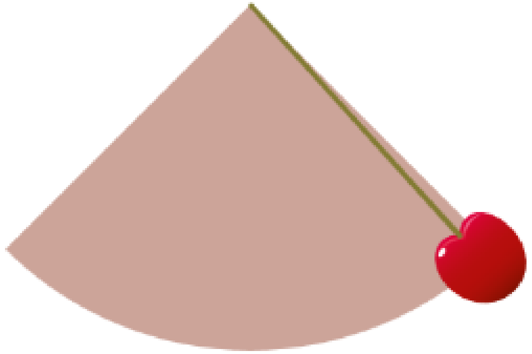
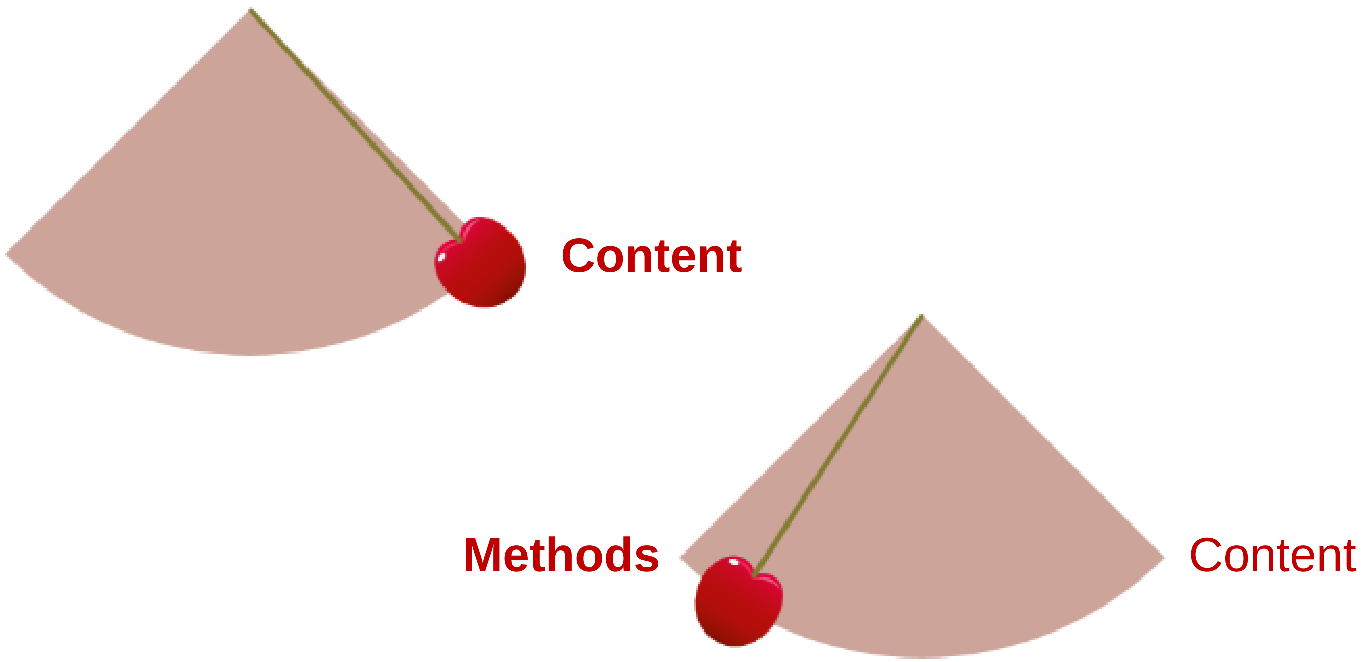
Initial focus of education literature*

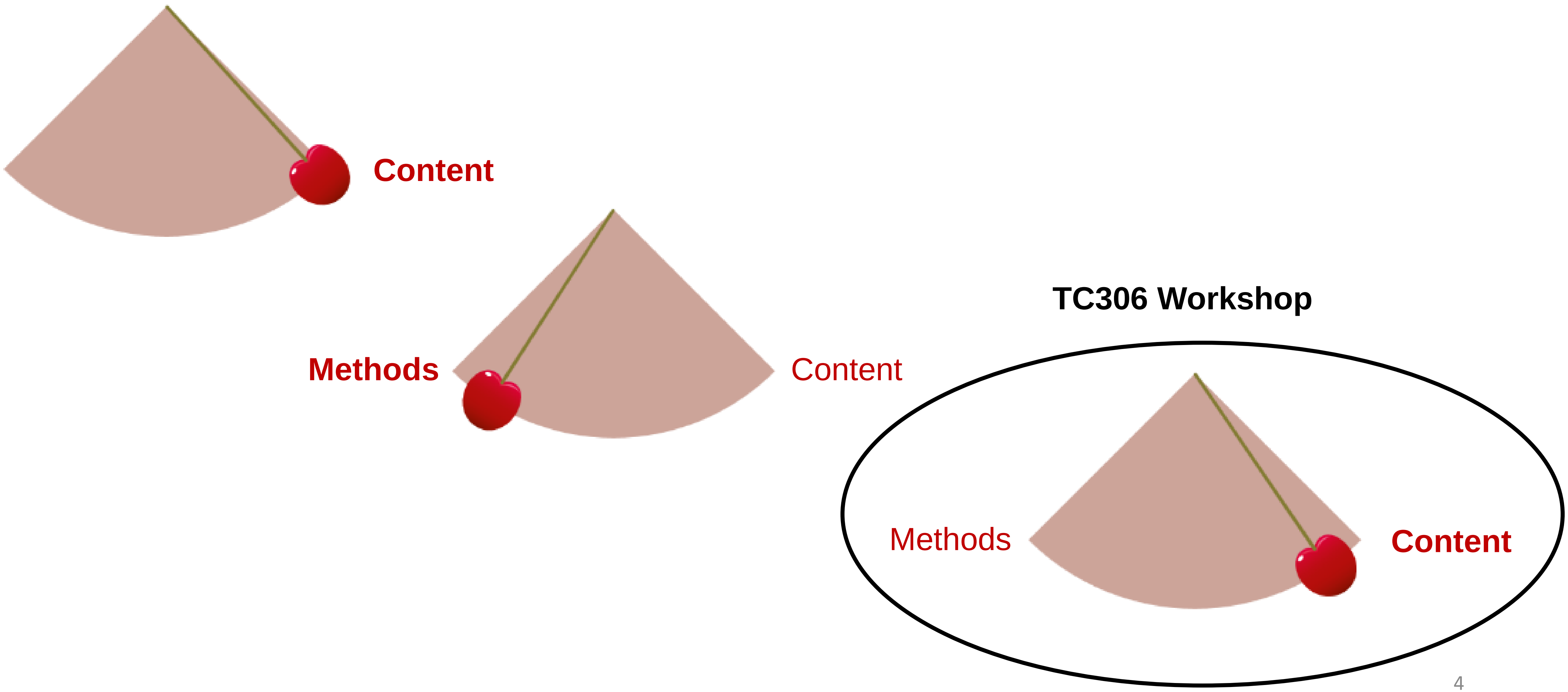


*Shulman (1986)

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

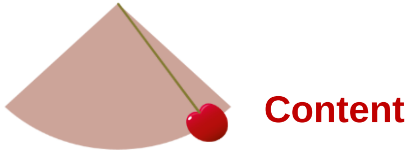
Panelists were invited to discuss:

(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
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  - 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

Atkinson 2012 **MAIN TOPICS**	Atkinson 2013 What a **graduate in civil engineering should be able to do**	What a **geotechnical engineer should also be able to do**
	TASKS RELATED TO MAIN TOPICS	
1. Basic Skills	Creat spreadsheet calculations Write a technical report	
2. Material Behavior and Properties	Estimate φ and Su from soil descriptions Sandcastle experiments, determine u	Do routine insitu and laboratory tests and interpret results Perform and validate numerical analyses
3. Investigations and Modeling	Describe soil and rock in engineering terms	Create a geotechnical model including design parameters
4. Groundwater	Draw flownet, calculate flow rate and U	
5. Slopes and walls	Calculate limiting undrained slope height and limiting drained slope angle Analyze slope stability in jointed rock Calculate stability of retaining walls	Design slopes and walls
6. Foundations	Calculate bearing capacity & settlements of simple shallow foundations Calculate capacity of a single pile	Design simple foundations Design an embankment on soft ground Design piled foundations
7. Earthworks and materials	Determine compaction curve	Design earthworks + pavements

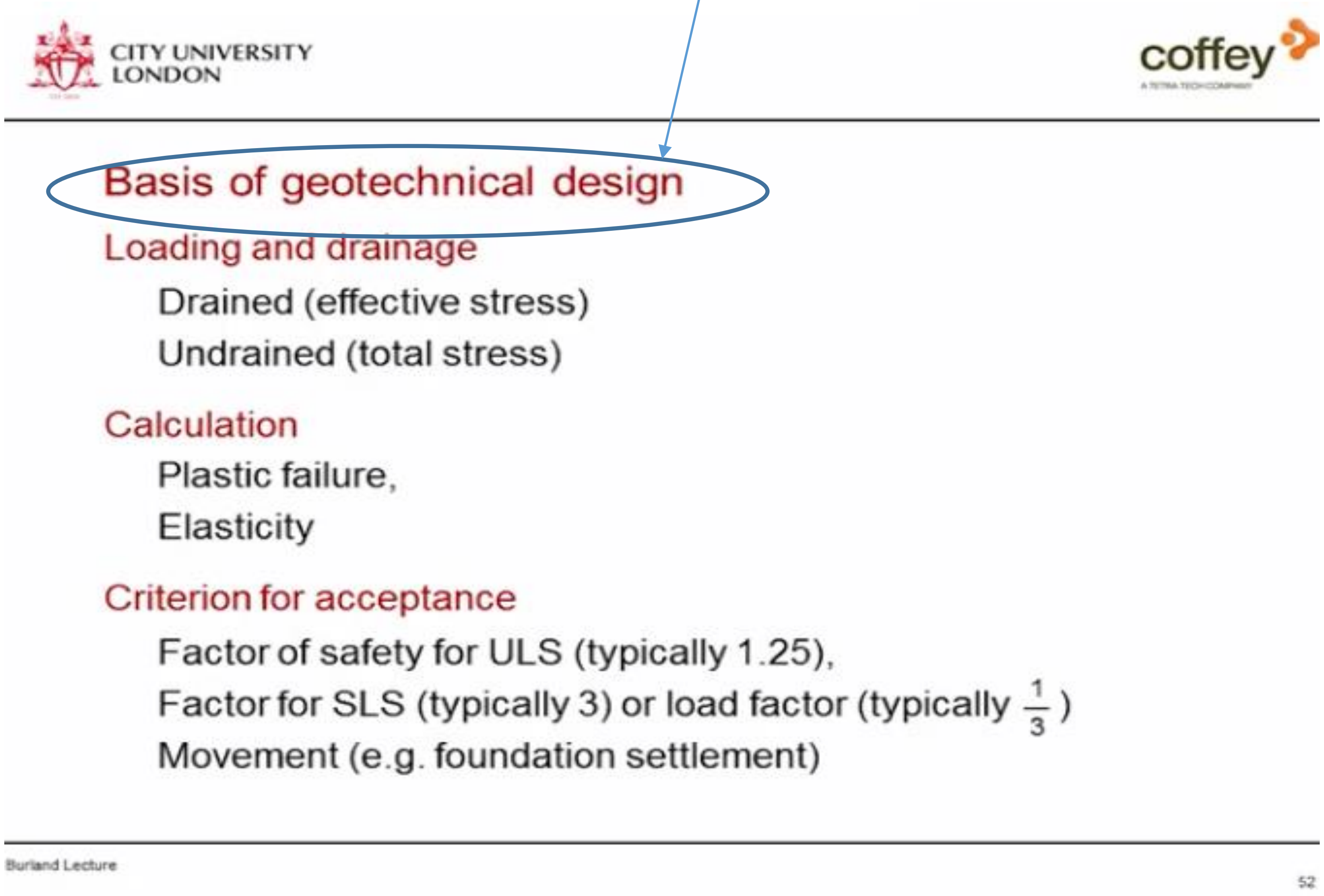
Wesley (2012, 2015) disagrees on how (see slide 17)

Graduate in civil engineering & engineering geology

Atkinson 2012 **MAIN TOPICS**	Atkinson 2013 What a **graduate in civil engineering should be able to do** **TASKS RELATED TO MAIN TOPICS**	Atkinson 2016 The minimum that **graduates in civil engineering or engineering geology should be able to do** **MAIN TASKS** • Components of main tasks
		EVALUATE DESIGN PARAMETERS
2. Material Behavior and Properties	Estimate φ and Su from soil descriptions Sandcastle experiments, determine u	• Describe soil, determine LI, D_R, estimate parameters (φ'c), Su, Strength-State, Eo(Su)
		MODEL THE GROUND • Describe the geological history
3. Investigations and Modeling	Describe soil and rock in engineering terms	•Create a 3D geotechnical model = materials+locations in 3D + engineering properties= strength, stiffness, drainage
		DESIGN SIMPLE SLOPE AND FOUNDATIONS
4. Groundwater	Draw flownet, calculate flow rate and U	• Construct flownet for steady-state seepage
5. Slopes and walls	Calculate limiting undrained slope height and limiting drained slope angle Analyze slope stability in jointed rock Calculate stability of retaining walls	•Design a safe slope, use critical state friction angle (Slide 54) • Analyze rock slope • Calculate limiting active and passive pressures on walls using critical state strength
6. Foundations	Calculate bearing capacity & settlements of simple shallow foundations Calculate capacity of a single pile	• Design foundation using bearing capacity concepts or elasticity theory, calculate amount and time for settlement
7. Earthworks and materials	Determine compaction curve	

all/some/any in agreement?

“How to teach”: situate big ideas within big vistas
(an example of how experts structure knowledge)



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?**

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  - 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?