International Webinar Series

Geoenvironmental Engineering: Polluted Land, Waste Management & Sustainability/Resiliency

Teaching Environmental Geotechnics, Behind the Scenes

Marina Pantazidou, National Technical University of Athens, April 2, 2021

Behind the scenes?

- Behind the scenes **of our brain**

Presentation Subtitle

Why both **students** and **teachers** can benefit from understanding (a little bit) how the brain works

Objectives of the presentation

- Interest you in connections between teaching and how the brain works
- Focus on some fundamentals of environmental geotechnics (polluted land)

and hopefully

- Motivate you to read open-access paper by Pantazidou & Kandris (2020) on **Redesigning an Environmental Geotechnics Course** and visit its online supplement

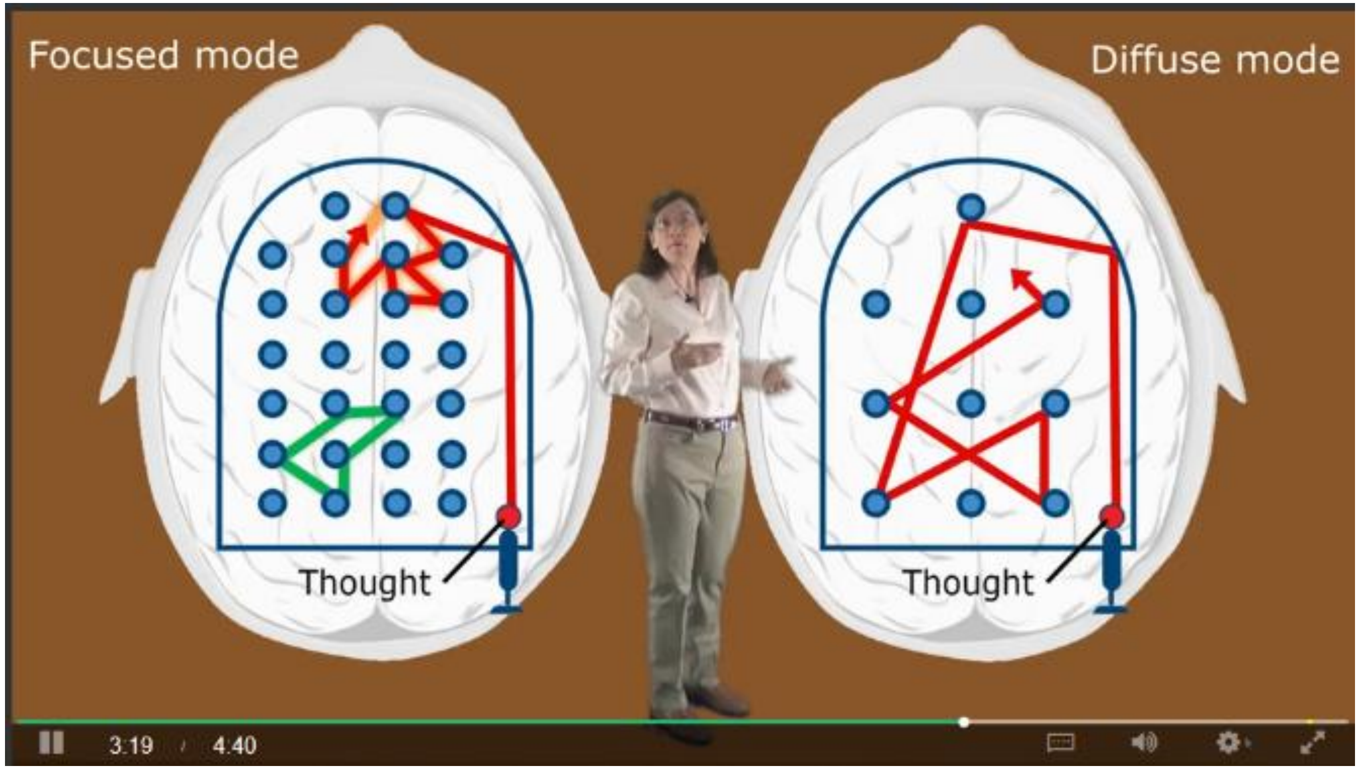
Redesign was prompted by creating an online version of an existing lecture-based course

Outcomes

- By the end of this session you should able to
  - Recognize evidence-based practices you already use in your teaching FOR TEACHERS
  - Identify (additional) evidence-based practices for enhanced teaching and learning
  - Apply such practices for organizing your teaching and learning (=self study)
  - Locate additional resources for how learning works

Inspiration for the view point of the presentation (1/2)

- Most popular MOOC* of all times "Learning how to Learn" – useful to both teachers and students



Oakley and Sejnowski (2021)

* MOOC = Massive Open Online Course

Inspiration for the view point of the presentation (2/2)

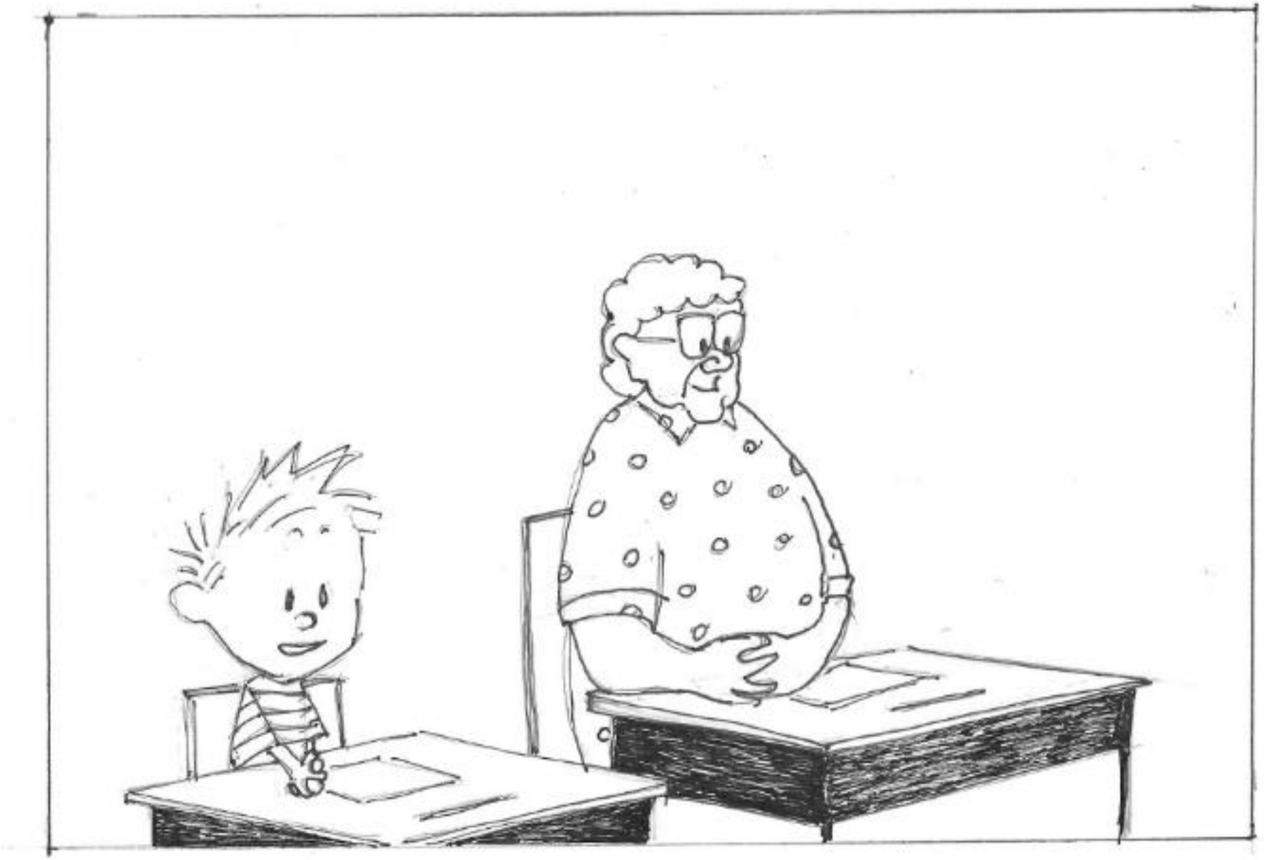
- Most popular MOOC of all times "Learning how to Learn" – **designed for college students**, useful to both **teachers** and **students**
- PREMISE We are not consciously aware of how our brains work. **We can learn more easily if we understand some of the basics about how our brain works**.
- **Q**: How does this course manage to be useful to both **teachers** and **learners**?
- **A**: Because it helps improve both how we **teach** and how we **learn**

learners

Teachers and ~~students~~ in antithetical positions?

Watterson (1994)

Teaching and learning have a lot in common…

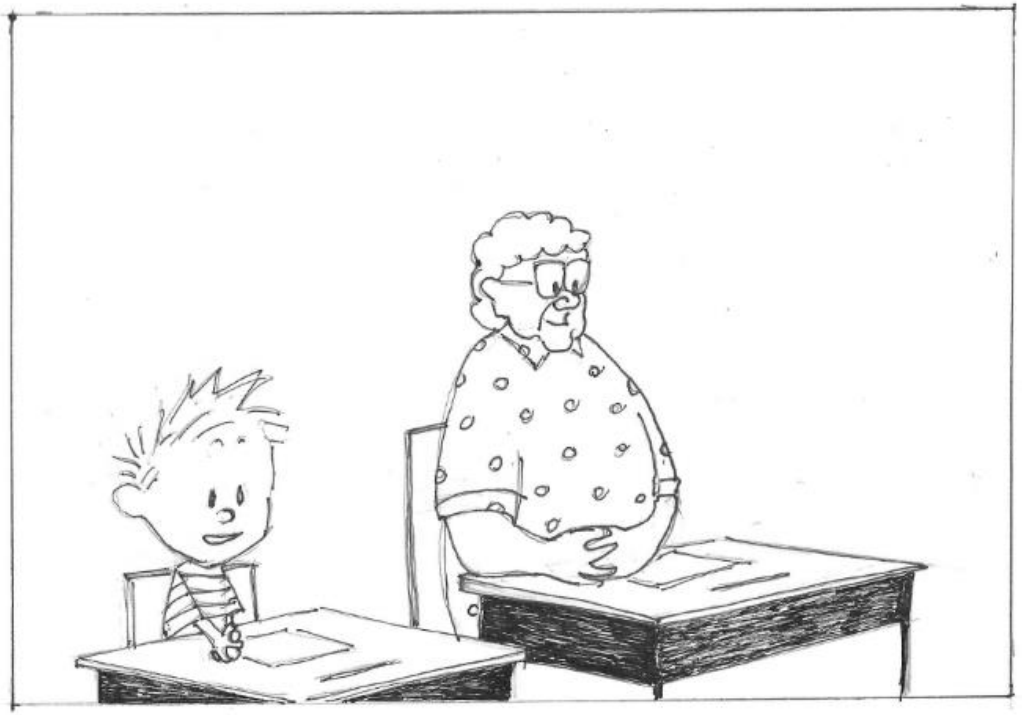


… same evidence-based tools for teachers and learners

Evidence (=research) often confirms teaching and learning intuitions – but not always

Q: Why not always?

A: Because sometimes the brain does counter-intuitive things!



Elements of (re)designing a course

STARTING POINT: HOW LEARNING WORKS

- Create **hooks** in the brain
  - Set the stage for the course with **Essential Questions**
  - Provide sign posts with **Main Points**
  - Place specifics within big picture first: **Qualitative → Quantitative** FOR TEACHERS MOSTLY
  - Create and champion the use of **Recall Questions**
  - Connections with reality: **Case Studies**
- Create **motivational hooks**
  - Clear goals for motivation: **Learning Outcomes**

STARTING POINT: CONTENT

- One topic-specific issue (contaminant transport)

Set the Stage with Essential Questions

- **Essential questions** help us introduce big ideas
- Big ideas help us focus our attention on what is worth spending time on
- FOR TEACHERS Check out Wiggins & McTighe (2005)
- **The most essential question**:
  - **Why do we care?**
  - Why is it important?
  - How important? So important that is worth teaching to everyone!

Essential Questions for Polluted Land

- **What is the danger (from pollutants)?**
  - distinguish danger from risk
- **Where will the pollutant go, how will it behave?**
  - introduce/review the science base of the course
- **What can we do to reduce the danger?**
  - engineering: connection with first essential question
- **When are things* relatively easy or difficult and why?**
  - a glimpse of expertise

* things = contaminated sites

Truly Essential Questions, phrased without jargon

- **What is the danger (from pollutants)**
- Why do we base remediation decisions on risk and not on danger?
- **Where will the pollutant go, how will it behave?**
- What are the main mechanisms of pollutant spreading?
- **What can we do to reduce the danger?**
- What are the main remediation technologies?
- **When are things* relatively easy or difficult and why?**
- Which are the major challenges for site remediation?

*** things = contaminated sites**

Essential Questions ↔ Related Course Units

Essential Questions	Related Course Units
	Unit 1. Setting the stage – Introduction: **case studies of contaminated sites**, introduction of essential questions, legislation, sources and characteristics of contaminants)
What is the danger (from pollutants)?	**Unit 2**. Risk Assessment
Where will the pollutant go, how will it behave?	**Unit 3**. Mechanisms of pollution spreading (qualitative description)
	Unit 4. Subsurface flow
	Unit 5. Modeling of physical systems
	Unit 6. Soil-contaminant interaction
	Unit 7. Contaminant transport in groundwater (quantitative-mathematical description)
What can we do to reduce the danger?	**Unit 8**. Remediation technologies for contaminated sites
	Unit 9. Landfill liner design and materials
When are things* relatively easy or difficult and why?	**Unit 10**. Wrapping up: answering** essential questions (Synthesis from prior units)

* things = contaminated sites

** the answer to this last question is built gradually through the course

Provide sign posts with Main Points

UNIT 4: Subsurface flow: Darcy's law

- For groundwater flow, **Darcy velocity** is a function of:
  (1) characteristics of the flow field: hydraulic gradient
  (2) the soil: hydraulic conductivity
- The hydraulic gradients of natural groundwater movement are low, e.g. common values range between 0.001 and 0.01
  - hydraulic gradient is written as decimal, not percentage, e.g. 0.001 (not ~~0.1%~~)
- The hydraulic conductivity of the soil varies within 10+ orders of magnitude

Main Points: Groundwater Flow (cont'd)

UNIT 4: Subsurface flow: Velocity of groundwater movement & of contaminant spreading (advection velocity)

- Attention! Depending on the thematic field, the term "groundwater velocity" may correspond to different concept
- In Environmental Geotechnics we should be careful not to use loosely the term "**groundwater velocity**", which refers to the **seepage velocity**, v_s (and not to Darcy velocity)
- The terms "average linear velocity" and "seepage velocity" refer to the same quantity (advection velocity)

Main Points are rare in lecture notes

STUDENTS

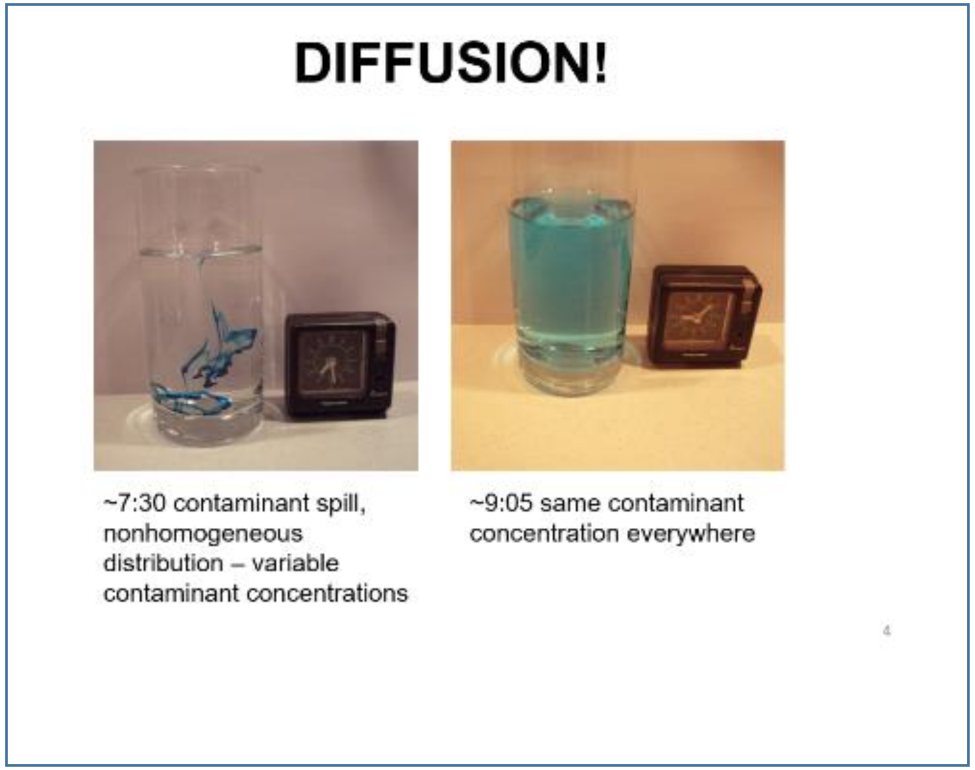
- Phrase your own, rephrase your professor's

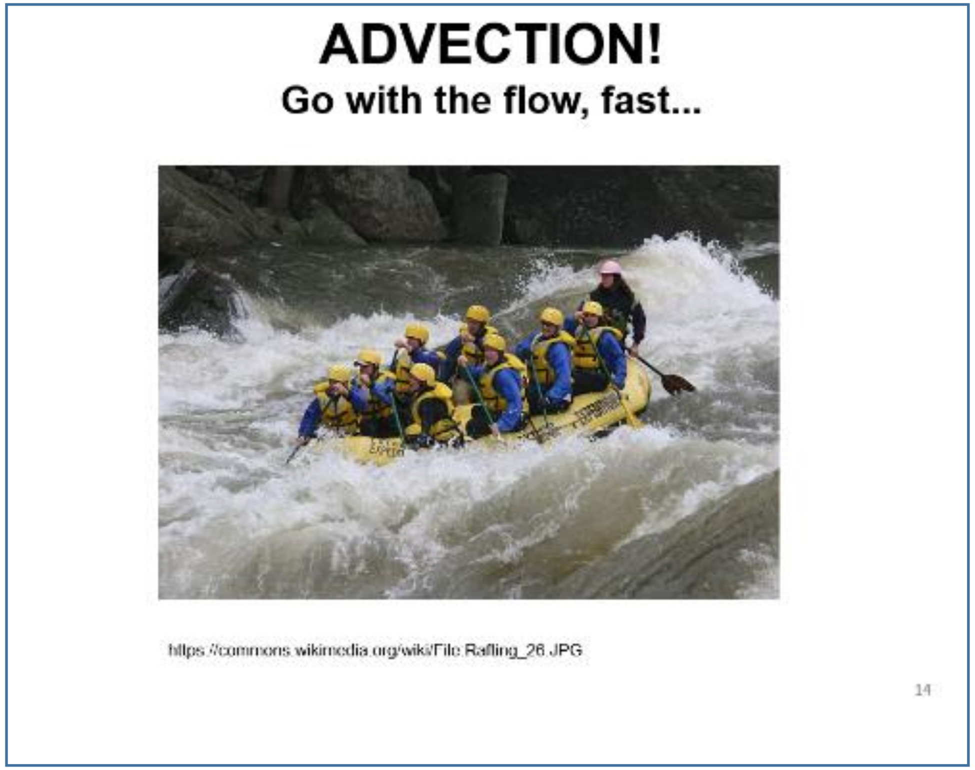
TEACHERS

- The "too easy" objection: "I don't want to spoon feed my students"
- Give students the equivalent of **training wheels in children's bicycles** (Dreyfus & Dreyfus, 1986), they will outgrow them faster
- Add your own to the pool of main points

Transition from Qualitative (big picture) to Quantitative

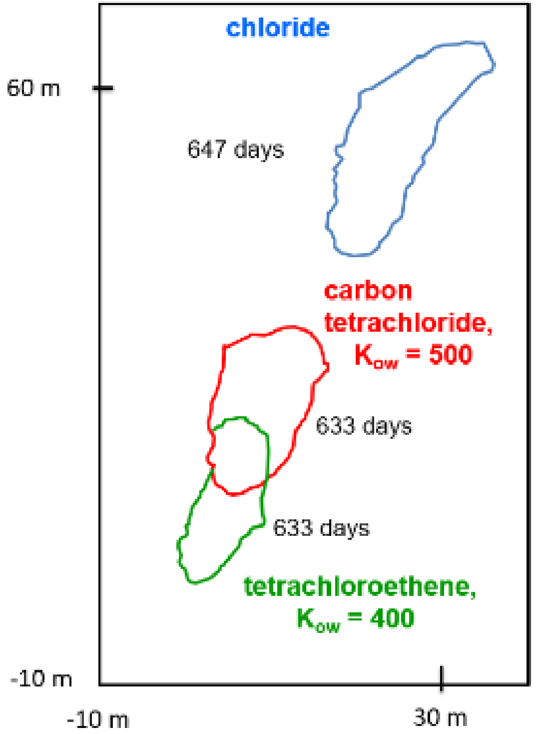
- Start with qualitative descriptions of the mechanisms of contaminant transport in water (+ great simulations from MIT course) FOR TEACHERS MOSTLY





Transition from Qualitative to Quantitative (cont'd)

- Show the qualitative effect of sorption before introducing the quantitative expression for the retardation factor



Injected substances: retardation due to sorption

Roberts et al. (1986), Fig. 5

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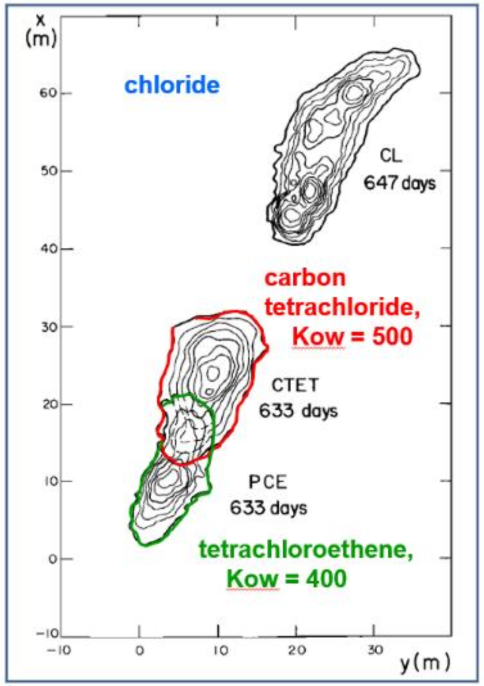


[Tracer experiment at Borden](): Roberts et al. (1986)

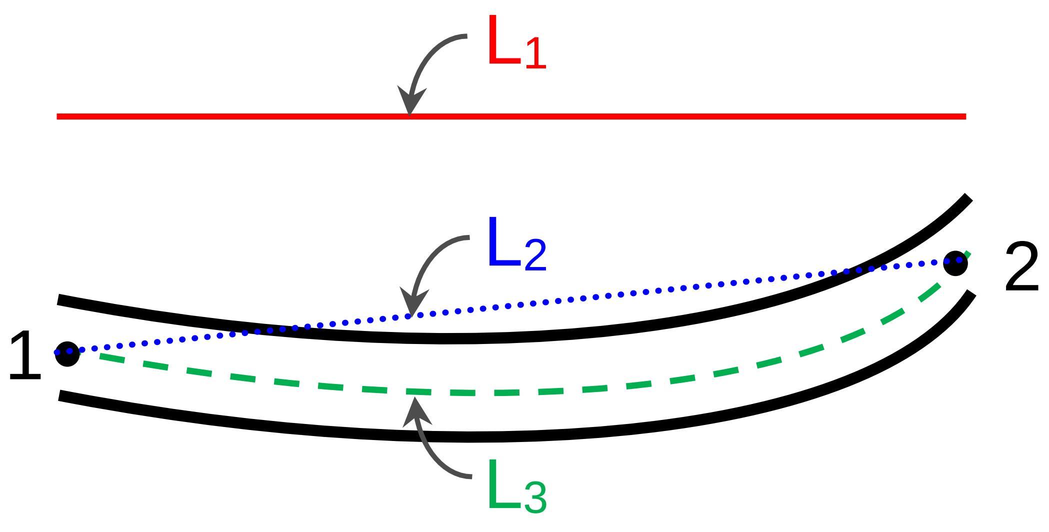
The power of Recall Questions (it is a term)

- Broader term: **retrieval exercises** (e.g. explain a concept, make an inference)
- Alternative term: question for comprehension
- Featured in almost all MOOCs – not necessarily the same as the poll questions recently popular in webinars
- Ample research evidence that **meaningful recall questions strengthen learning**, e.g. Karpicke and Grimaldi (2012):
  - "every time we retrieve knowledge, that knowledge is altered, and the ability to reconstruct that knowledge again in the future is enhanced"
  - students (like their professors) are unaware of the beneficial effect of retrieval on learning

Recall Questions (1/2)

Question for understanding

For water flow between points 1 and 2 in the curved tube in the sketch below, when calculating hydraulic gradient $i = \Delta h_{1,2}/L$, (a) $L = L_1$, (b) $L = L_2$ or (c) $L = L_3$?



UNIT 4
Subsurface flow:
hydraulic gradient

correct answer in the paper

Recall Questions (2/2)

UNIT 7 **Contaminant Transport**

- **An aqueous solution of two contaminants has been released** in the subsurface and reached the water table. You use the same transport equation to study their spreading in groundwater. From the parameters listed below, mark which ones you expect to be the same and which different in the equation used to describe the spreading of each contaminant:

- Duration of contaminant release	Same ☐	Different ☐
- Contaminant concentration at the source	Same ☐	Different ☐
- Advection velocity	Same ☐	Different ☐
- Retardation factor	Same ☐	Different ☐
- Coefficient of diffusion	Same ☐	Different ☐
- Coefficient of mechanical dispersion	Same ☐	Different ☐
- Half life	Same ☐	Different ☐

Recall Questions (2/2)

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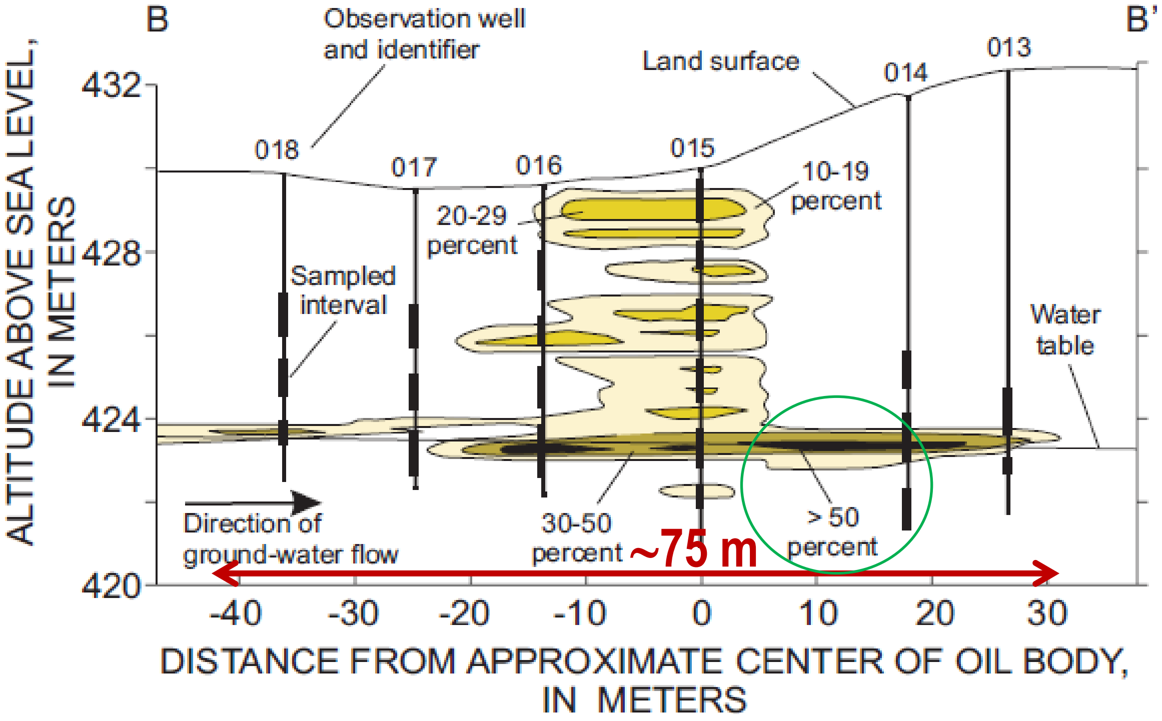
- Coefficient of mechanical dispersion	**Same** ☐	Different ☐
- Half life	Same ☐	**Different** ☐

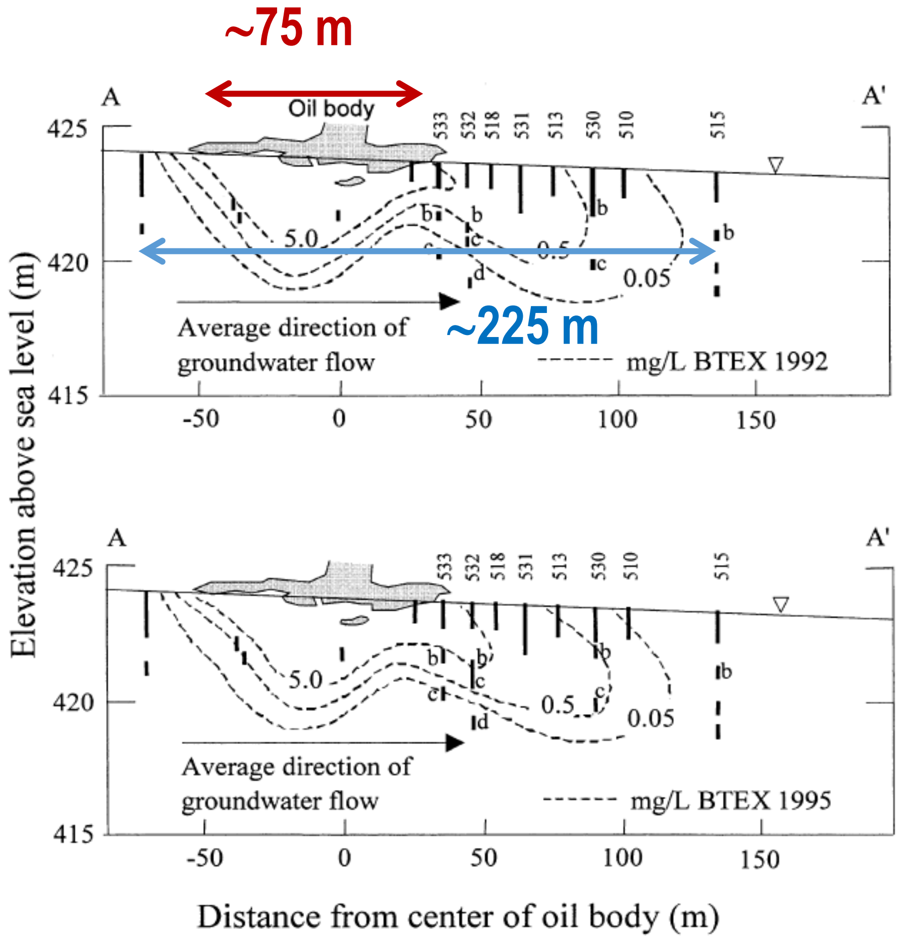
Connections with reality: Case Studies

- Case studies in Lectures
  - Risk assessment: Graces Quarters (USEPA, 2004)
  - Pollutant fate & transport: Borden experimental site (Mackay et al., 1986; Roberts et al., 1986), Bemidji oil spill site (USGS, 1998; Cozzarelli et al., 2001)
- Problems based on case studies
  - Groundwater flow: refinery in Iran (calculate travel time of dissolved oil constituents) (Vaezihir et al., 2012)
  - Fate of contaminants: non aqueous phase spill in Charleston, West Virginia (discuss modes of contaminant transport) (Bernstein, 2014)

Emblematic NAPL Case Study: Bemidji, MN



USGS (1988)



Cozzarelli et al. (2001)

Learning Outcomes: Motivational hook

- Learning outcomes
  - concern the psychological-behavioral aspects of learning
  - offer clear goals to students and create **positive expectancies** (Ambrose et al., 2010), especially when connections to assessment are explicit
  - are tasks students do $\rightarrow$ give teachers clear directions for assessment
  - are particularly suitable for engineering: **consistent with performance-based design**

Learning Objectives vs Learning Outcomes

- Broad learning **objectives** for the course

The goal is achieved if at the end of the course the students:	
(1)	can locate reliable data on the effects of contaminants on human health;
(2)	are **confident in applying principles of subsurface flow**, soil-contaminant interaction and contaminant transport to problems of contamination and restoration of the subsurface;
(3)	are able to address the geoenvironmental aspects of landfill and clay barrier design;
(4)	are **familiar** with a wide range of remediation technologies;
(5)	are able to take initiatives related to modeling, i.e. related to the formulation of a simplified problem that admits solution;
(6)	are **aware** of some social or public policy dimensions of the problems of subsurface contamination and restoration.

Introducing Learning Outcomes to students

Until now, what did we learn/what can we do with what we learned?

Specifying detailed learning outcomes

- From the first, introductory lesson: “The goal is achieved if at the end of the course the **students are confident in applying** principles of subsurface flow”
  - How can I be more specific about what you should be able to do?

Common features of groundwater flow problems we can handle

- Flow can be approximated as **one-dimensional** (at least in parts)
- Hydraulic head **does not change** (significantly) **with time**

Learning Outcomes: Groundwater Flow

What can I do with what I learned?
For 1-D problems (or 1-D simplifications of 2-D flow fields), and constant hydraulic gradient (in time): (1) I can **calculate** hydraulic head and piezometric head; (2) I can read potentiometric maps (i.e. hydraulic head maps), i.e. I can tell the direction of groundwater flow and calculate hydraulic gradient; (3) I can **apply** Darcy's law to calculate velocity, discharge, or hydraulic head; (4) I can perform calculations for advection-driven transport of contaminants (e.g. travel time).

Learning Outcomes: Contaminant Transport

What can I do with what I learned?
1. I can **estimate** the relative contribution of transport **phenomena** for specific combinations of pollutants, soils and characteristics of the flow and transport fields (term project)
2. I **am familiar** with **searching in the literature** for values of transport parameters (homework assignments)
3. I **can back** reasonable estimates for the values of the **parameters** involved in a problem of contaminant transport (term project)
4. I **am aware** of a variety of **analytical solutions** of the equation for contaminant transport and I understand the limitations of each one (homework assignment and final exam)
5. I can **select** from a variety of **analytical solutions** of the transport equation the one that fits better the geometry of a contaminant re-lease and the expected contribution of the transport phenomena (term project)

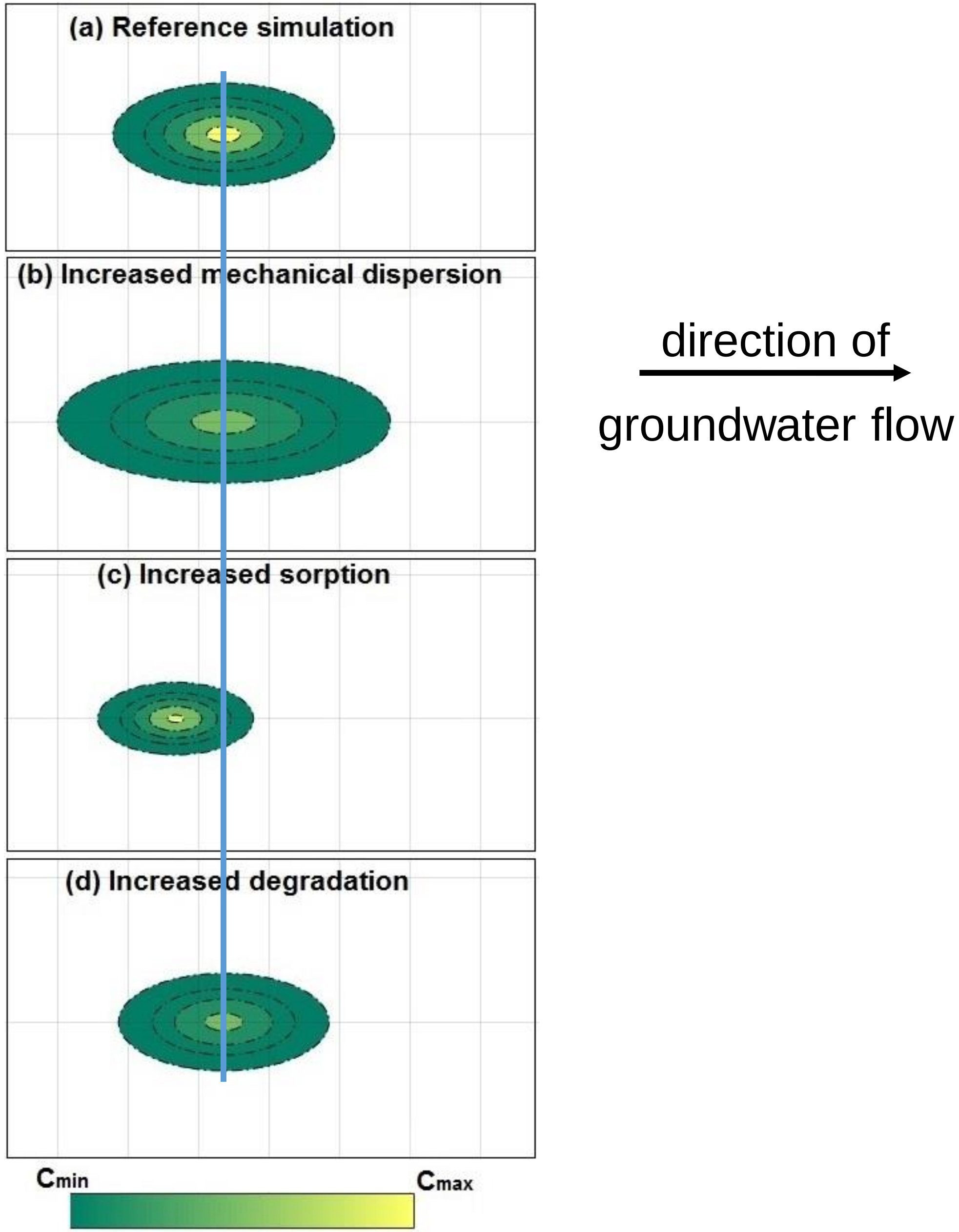
Two ways to approach course design

- **Start from how learning works** (presentation so far)
  - Approach content accordingly (Ambrose et al., 2010; Wiggings & McTigue, 2005)
- **Start from content** and students' difficulties (one example on next slide to show the difference)
  - Introduce topic-specific learning enhancements, produce custom-made educational material

Both approaches are needed!

Topic-specific issue: relative contribution of transport phenomena

- Contaminant plume due to instantaneous release from point source
- Effect of each transport phenomenon on:
    - Plume center
    - Plume extent
    - Maximum concentration



Main points

- **Research** on education and on the sciences of the brain has progressed to the point that it **can back up specific teaching & learning practices**
- Some practices are compatible with the architecture of the brain
  - e.g. build course around **essential questions**, state **main points**
- Some practices are supported by solid research results showing they produce better learning
  - e.g. **recall questions**

Outcomes – geoenvironmental engineering students

By the end of this session you should be able to

- Name tools you can use to enhance teaching and learning
- Apply at least one tool (recall question) right at the end of this presentation:
    - Before going on with your next task, spend a couple minutes to **question yourself** about **2-3 main points of your choice**
- Peruse educational material to test your knowledge of geoenvironmental engineering

Outcomes – geoenvironmental engineering teachers

We are at the end of this session. Are you be able to

- Recognize evidence-based practices you already use in your teaching?
- Recognize the justification of these practices?
- Name tools you can use to enhance teaching and learning?

Outcomes – geoenvironmental engineering teachers

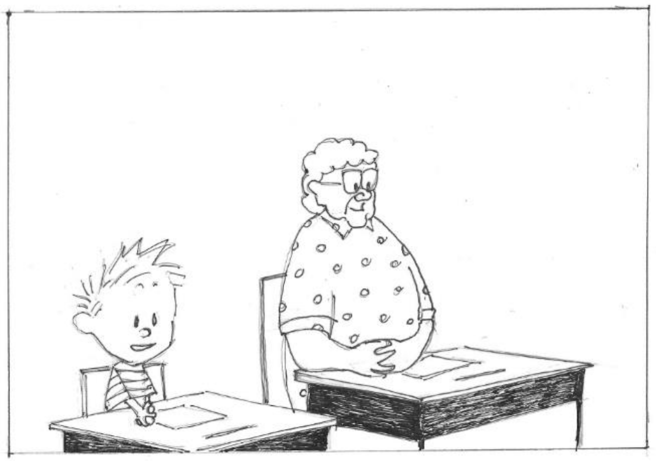
long term outcomes

After the end of this session, you can

- Name tools you can use to enhance teaching and learning
- Evaluate applications of the tools we discussed to geoenvironmental engineering
- Contribute to communal teaching resources for geoenvironmental engineering

Conclusion

- We can **all** contribute to communal teaching resources for geotechnical & geoenvironmental engineering
- **Students**: by communicating your difficulties in understanding
- **Teachers**: by sharing the educational material we are proud of



TC306, the Geo-Education Committee of the ISSMGE, would love to hear from you

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Thank you for attending
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