Engineering Education Research meets Engineering Instruction: Innovations in Civil Engineering Education

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Parthenon, Acropolis, Athens, Greece,
5th Century BC

Hagia Sophia, Istanbul, Turkey,
6th Century AD

Hagia Sophia, interior

Cathedral at Reims, France,
13th Century AD

Reims Cathedral, front

Selimiye Mosque, Edirne, Turkey

16th Century AD

Selimiye Mosque, interior

Board of Trade, Chicago, USA, 1930

Guggenheim Museum, Bilbao, Spain, 1997

Analogy made in this presentation

- The theory of mechanics and research in structural engineering have enlarged the repertoire of structural engineering (what can be built and who can build it)
- The theories of learning and research in engineering education (REE) is bound to enlarge the scope of engineering education (what and how can be taught and by whom)
  - Technology alone solves logistical problems, it needs REE to also address pedagogical and cognitive issues

Presentation contents

- An aspect of the dominant instructional theory: importance of prior conceptions
- Examples of students' understanding of key concepts
- Research into uncovering students' prior conceptions
- Conclusions: our role as instructors

Instructional theory: adopting the learner's perspective (student-centered teaching)

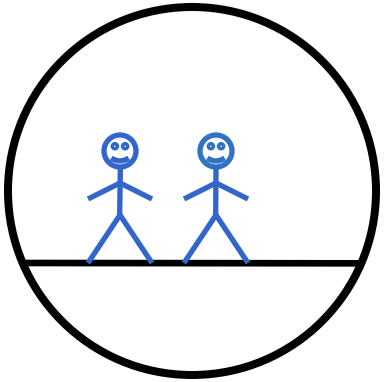
- People construct new knowledge and understand things based on what they already know and believe*
- Relevance to instruction
  - Instructional decisions have to take into account the students' pre-existing knowledge (preconceptions, misconceptions, incomplete knowledge, fragmented knowledge)
- If students' initial ideas and beliefs are ignored, the understandings that they develop can be very different from what the teacher intends*

*Bransford et al. (2000)

Research on learning of domain-specific topics

- Pre-existing knowledge is accessed through qualitative diagnostic questions
  - ~~What is the shape of the earth?~~
  - If you were to walk for many days in a straight line where would you end up?

    (Vosniadou and Brewer, 1992)



- Students are aware of the difference between question types
  - "Do you want me to tell you what I really believe or give the correct answer?"

    (Mazur, 1997)

Application of findings on learning of domain-specific topics: chemistry → engineering

"Greek" coffee (in Greece)

Instant coffee

Environmental Geotechnics class, NTUA

Is an Atom of Copper Malleable?

Ruth Ben-Zvi, Bat-Sheva Eylon, and Judith Silberstein
The Science Teaching Department, Weizmann Institute of Science, Rehovot, 76100, ISRAEL

The atomic model plays a central role in the study of chemistry and is usually introduced very early in the curriculum. It is therefore important to study the mental pictures of the atomic model formed by students at an early stage of their studies, since misunderstanding this model may prevent meaningful learning at later stages. In the present study an attempt was made to find out students' views about atoms after they have been exposed to chemistry studies for about half a year. The conclusions of this study can be useful

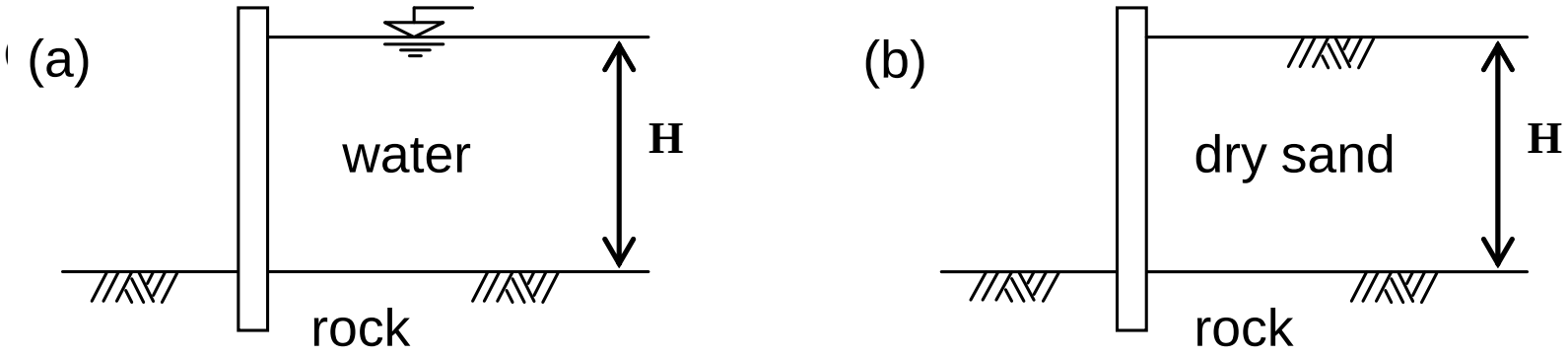
Table 1. Distribution of the "Properties" Attributed to the Atom (N = 288)—Stage 1

Category	"Origin" of the Atom		Properties	%
1)	Solid	→	Solid	41.3
	Gas	→	Gas	
2)	Solid / Gas	→ +	Solid / Gas	4.9

Ben-Zvi et al. (1986), J. of Chemical Education

Research on understanding of specific engineering topics in geotechnics

- Two diagnostic questions for geotechnical engineering
  - (1) A retaining structure is embedded in solid, impermeable bedrock to contain (a) water and (b) dry sand, reaching the same height. In which case does the retaining wall feel a greater force? Why is that so?



(Pantazidou, 2000)

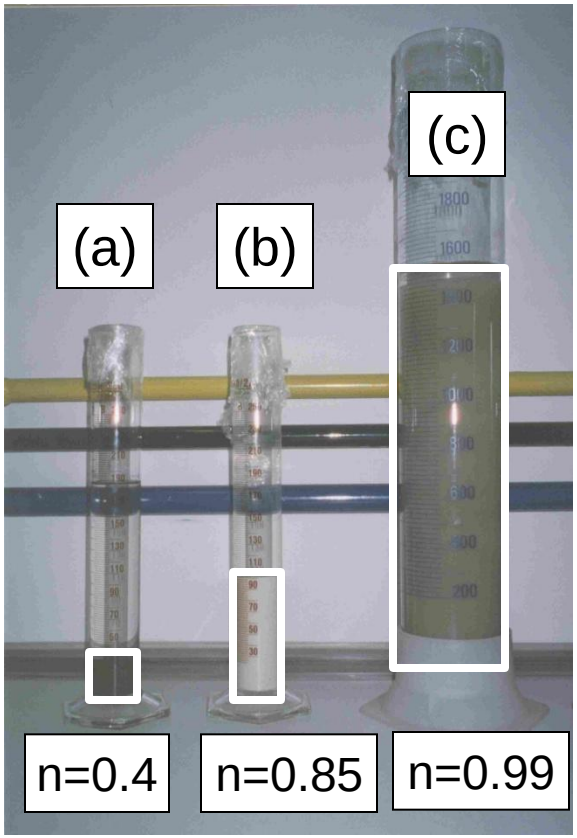
Research on understanding of specific engineering topics in geotechnics, cont'd

- Two diagnostic questions for geotechnical engineering
  - (2) In your opinion, in which type of soil you may encounter a higher porosity, in a sand or a clay? How do you justify your opinion?

(Pantazidou, 2009)

(a) sand
(b) kaolinite
(c) bentonite

Three soil columns with the same mass of dry soil = 40g



Research on understanding of specific engineering topics: statics

What is "Cognition" for Statics?

Many little bits of knowledge: principles, concepts, skills… what to choose?

Are there certain ideas that, if mastered, give students leverage on other ideas?

Are there errors students consistently make or ideas they seem not to grasp?

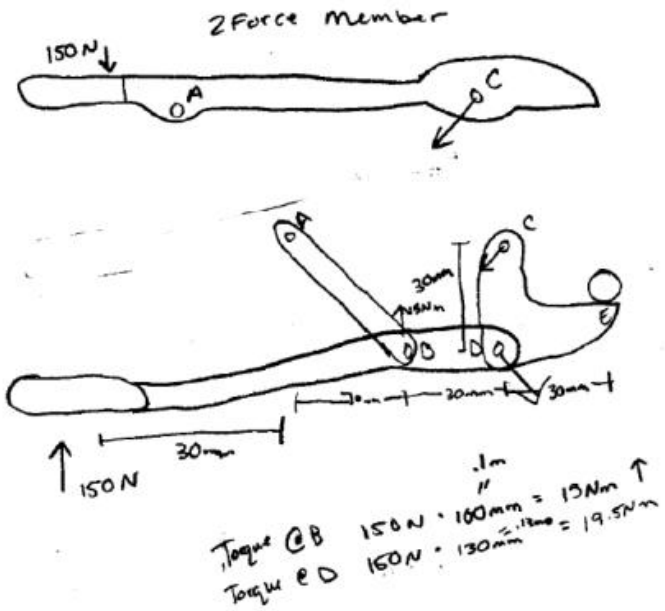
PAUL STEIF

Steif (2011)

ask fundamental questions about <u>learning</u> in a discipline

Research on understanding of specific engineering topics: statics, cont'd

Typical Student Solution with Errors



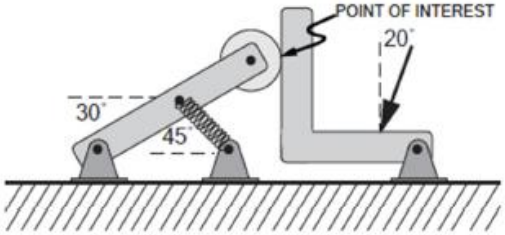
PAUL STEIF

Steif (2011)

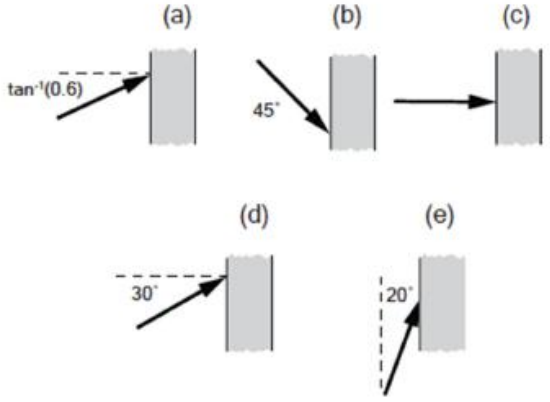
identify systematically students' errors and misconceptions, classify them in categories (Steif, 2004)

Research on understanding of specific engineering topics: statics, cont'd

12. The L-shaped arm is kept in the position shown. The pin that the roller rotates on is frictionless. The coefficient of friction between the roller and the arm is 0.6.



What is the direction of the force exerted by the roller on the arm at the point of interest?



PAUL STEIF

Steif (2011)

develop and validate statics concept inventory of 27 questions from 5 classes of problems
Steif & Dantzler (2005)
Steif & Hansen (2006)

Some conclusions about the needs of the "customers" (us!)

- Research in engineering education has gaps on topics such as:
  - prior conceptions of students relevant to key topics (systematic efforts in some disciplines! *)
- The communities of the civil engineering sub-disciplines need to pursue collaborations with engineering education researchers in order to:
  - address topic-specific gaps
  - make efforts of instructors cumulative (peer-used educational materials, like textbooks!)

*NRC (2012): Report on Discipline-Based Education Research in Science & Engineering

Conclusions as a motto*

- The dual role of engineering instructors (with regards to engineering education research):
  - informed and demanding customers!
  - thoughtful and eager collaborators!

*a short expression of a guiding principle (online Webster)

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thank you!