# *Introducing students to the culture of physics:*

# *Explicating elements of the hidden curriculum*

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- Learning a complex field of knowledge is more of a complex process than we give it credit for – because so much of it is natural to us (we have "phenomenological-primitives" of learning and folk psychology).
- But to get it right we have to get beyond the p-prims and do the science.

# *Definition*

- The “hidden curriculum” is made up of those elements of learning our subject that we expect our students to learn without our being explicit about them – those items that are supposed to “come along for the ride”.
- We may not even be aware of them ourselves.

# *Some elements of the HC*

- Epistemology – learn what is accepted as evidence for believing a particular result.

  Redish & Hammer, *Am. J. Phys.*, **77** (2009) 629-642.

- Ontology – What kind of “things” do we talk about and what is their nature?

  Gupta, Hammer, & Redish, JLS, **19**:3 (2010) 285-321.

- Intuition – … ?
- Discourse – …?

# *Culture and Cognition and the HC*

- In order to go deeper than just "that-looks-good-to-me!" heuristics, we have to do some deep thinking about the nature of professionalism in physics.
- We need to develop some insight into how the culture of physics affects our cognitive processing and our thinking about the physical world.

## *The Hidden Curriculum through a cognitive lens*

# *Why the HC is hidden*

- Learning involves
  - *Association* – building access paths
  - *Compilation* – chunking separate bits of knowledge into an apparently unary piece
  - *Framing* – learning when particular bits of knowledge and activities are relevant
- These processes make it difficult for an expert to see the components of his/her knoweldge.
- To understand the HC
  we need to deconstruct expert thinking.

# A parable of Achilles

- We live in the age of the triumph of form. In mathematics, physics, music, the arts, and the social sciences, human knowledge and its progress seem to have been reduced in startling and powerful ways to a matter of essential formal structures and their transformations…. The axiomatic method rules, not only in mathematics but also in economics, linguistics, sometimes even music.

- On the other hand, common sense tells us that form is not substance: The blueprint is not the house, the recipe is not the dish, the computer simulation of weather does not rain on us. When Patroclos donned the armor of Achilles to battle the Trojans, what the Trojans first saw was the spectacular armor, and they naturally assumed it was Achilles, and were terrified, and so the armor by itself looked as if it was turning the battle. But it didn't take long for the Trojans to discover that it was just Achilles's armor, not Achilles himself, and then they had no pity…. Clearly the miracles accomplished by the armor depend on the invisible warrior inside.

from *The Way We Think: Conceptual Blending and the Mind's Hidden Complexities*, by Gilles Fauconnier and Mark Turner (Basic Books 2003), pp. 1-4.

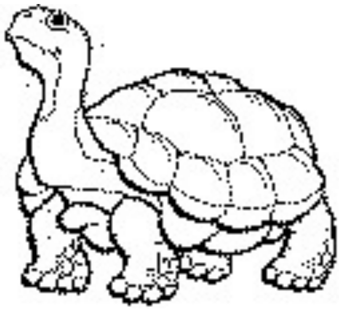
# *Two components of brain processing*

- Formal, linear, serial processing,
  driven by explicit articulable rules.
- Automatic, intuitive, parallel processing,
  often *not* articulable --
  our "*recognition software*."

- What are the implications for us?

# *A second parable of Achilles*

- T: "Well, now, let's take a little bit of the argument in that First Proposition -- just two steps, and the conclusion drawn from them. Kindly enter them in your notebook. And in order to refer to them conveniently, let's call them A, B, and Z: --
  - (A) Things that are equal to the same are equal to each other.
  - (B) The two sides of this Triangle are things that are equal to the same.
  - (Z) The two sides of this Triangle are equal to each other.



- T: Readers of Euclid will grant, I suppose, that Z follows logically from A and B, so that any one who accepts A and B as true, must accept Z as true?"
- A: "Undoubtedly! The youngest child in a High School -- as soon as High Schools are invented, which will not be till some two thousand years later -- will grant that."

from *What the Tortoise Said to Achilles*, by Lewis Carroll
*Mind* 4, No. 14 (April 1895) 278-280.

- T: "And might there not also he some reader who would say 'I accept A and B as true, but I don't accept the Hypothetical '?"

A: "Certainly there might. He, also, had better take to football."

T: "And neither of these readers," the Tortoise continued, "is as yet under any logical necessity to accept Z as true?"

A: "Quite so," Achilles assented.

T: "Well, now, I want you to consider me as a reader of the second kind, and to force me, logically, to accept Z as true."

A: "I'm to force you to accept Z, am I?" Achilles said musingly. "And your present position is that you accept A and B, but you don't accept the Hypothetical --"

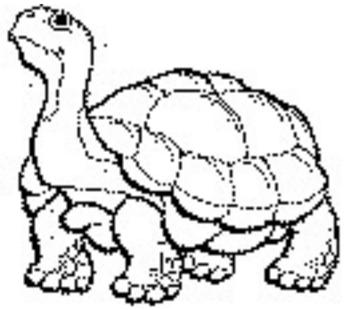
T: "Let's call it C," said the Tortoise.

A: "-- but you don't accept

- (C) If A and B are true, Z must be true. "

T: "That is my present position," said the Tortoise.

A: "Then I must ask you to accept C."



# *The critical importance of intuition*

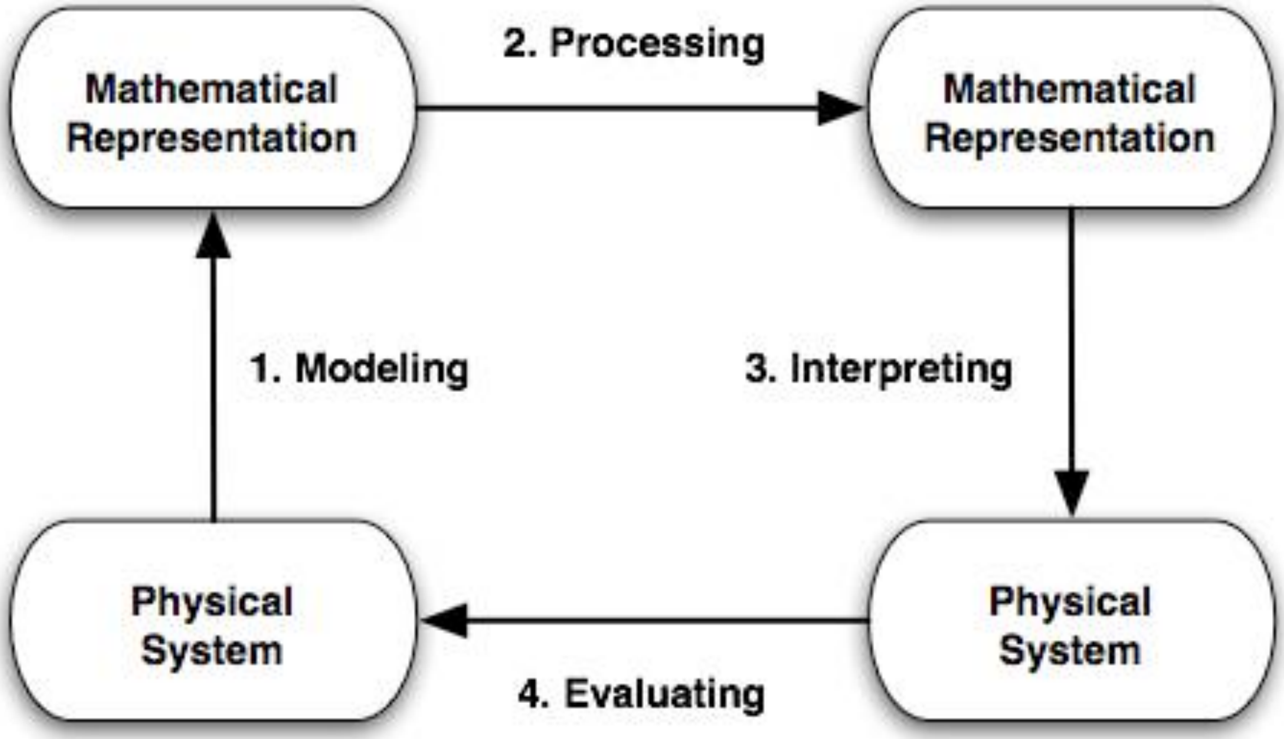
- The second parable of Achilles is rather startling – especially to a theoretical physicist.
  It's Zeno's paradox applied to logic!
- Why do my students ask "how did you get that next step?"
- The role of "the inner Achilles": even in formal proof our "recognition software" steps in to cut off the infinite chain.
  but: "Oh, I get it!" is NOT an element of formal logic.
- The character of these intuitive recognitions are cultural norms, learned as we become physicists.
- They play a role at different level than the formal,
  but they play a critical role even in interpreting the formal.

# *An example: A problem solving rubric from a popular intro text*

- Model!
  - Make simplifying assumptions.
- Visualize!
  - Draw a pictorial representation.
- Solve!
  - Do the math.
- Assess!
  - Check your result has the correct units, is reasonable, and answers the question.

**Good advice! Right?**

# *And it matches well the model of modeling that I use!*



# *A sample problem from a popular intro text (the one that gave the rubric)*

- On a hot 35 C day, you perspire 1.0 kg of water during your workout.
  - What volume is occupied by the evaporated water?
  - By what factor is this larger than the volume occupied by the liquid water?

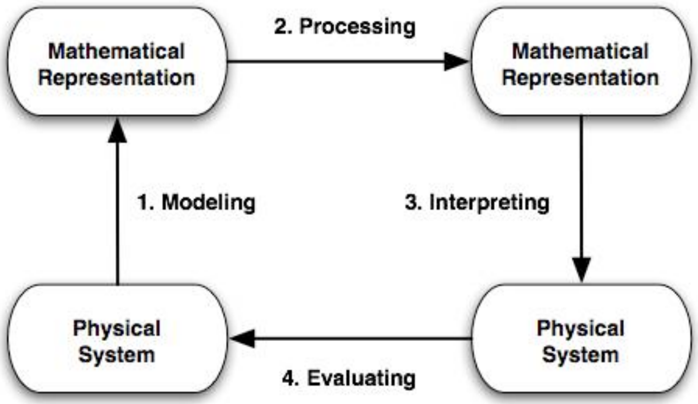
flickr photo by Jeff Mawer

# *The solution in the manual (note it follows the rubric!)*

- Model:
  - Assume the evaporated water is an ideal gas with a molar mass of 18 g/mole.
    Assume the pressure is 1 atm = 101.3 kPa.
- Visualize:
  - We are given $T = 35\ C + 273 = 308\ K.\quad n = 1000\ g(\text{1 mol/18 g})\text{=55.6 mol.}$
- Solve:
  - (a) $pV = nRT \Rightarrow V = \frac{nRT}{p} = \frac{(\text{55.6 mol})(\text{8,31 J/mol}\cdot\text{K})(\text{308 K})}{\text{101.3 kPa}} = 1.4\ \text{m}^3$
  - (b) In the liquid state ρ = 1000 kg/m$^3$
    (a simple calculation yields a factor of 1400).
- Assess:
  - Gases really do take up a lot more volume than the equivalent mass of a liquid!

# *What's missing here?*

- The 4-box model is the structural story, but not the cognitive one.
- The solution manual's answer fails to think about the problem physically – to *tell the story of the problem.*




**The steps of the rubric are gone through formally – but without the activation of a sense making intuition about molecules – and even about gases filling all available space!**

# *What's missing?*

- Building a sense of what's going on in the problem
- Tying the analysis not to a formal set of mapped rules (the armor), but to a sense of meaning – to everything we know and recognize about a system (the inner Achilles).

# *"Intuition" has many components*

- Identification of identity – when things are supposed to represent the same thing (as in being able to follow formal proof).
- Placing a problem in a broader context – "making meaning" by linking to many things we know about the world.

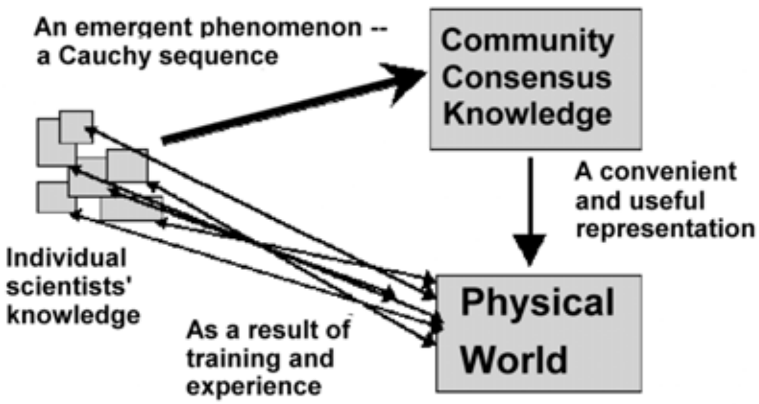
*The character of these intuitive recognitions are cultural norms, learned as we become physicists.*

- I snuck this in on your earlier.
  This has some serious implications.
- And it means that we have to go beyond just cognitive modeling.

## *The Hidden Curriculum through a socio-cultural lens*

# *Community cognitive standards*

- Many components of our HC arise as an emergent phenomenon from our interactions as a community.
- This has powerful implications when we consider interdisciplinary issues/



# *Within Physics*

- A part of what's hidden
  in our hidden curriculum is
  the ***discourse of the community***
  – learning to "talk the talk."
- Students perceive that what they are learning are facts and procedures.
- But they need to learn how to talk about physics problems and situations
  – first with others, and then by themselves.

# *Math in Physics*

- If many of our critical HC elements are community driven, when we go to different communities for service courses we might get something different from what we want.
- Units
- Parameters
- Do we *ever* need our students to be able to create an epsilon-delta proof?

# *Physics in Biology*

- If many of our critical HC elements are community driven, when we provide service courses for different communities, we need to understand how they use what we teach.
- Functional dependence
- Parameters
- Will they *ever* need to be able to calculate projectile motion or solve complex equations?

# *Can we teach/test for this? Some heuristics*

- Reduce success of direct memorization.
- Encourage “telling the story”, “describing what’s happening.”
- Use explicit representations – video and simulations – that tell the story in other than a formal way.
- Try to develop test questions that are easy to answer if you both know the formal and are telling the story – but are hard if you have only memorized the formalities.

# *Existing Reforms*

- We have focused on the value of the Tutorial model as helping students to learn to reason qualitatively.
- We have focused on the value of Group Problem Solving as helping students learn problem solving methods.
- I conjecture that one of the elements in their success is that students are learning to *carry out the conversation of physics*.

# *Conclusion*

- We often look at student failures and try to fix them by creating linear algorithms – as if the students were computers to be programmed.
- This sometimes works – because the inner Achilles comes along for the ride.

# *Conclusion*

- Many of the excellent PER reforms give students free rein to develop their inner Achilles.
- But if want to learn how to help them build an adaptive and flexible expertise, we probably should pay more explicit research attention to understanding and modeling intuition development – from the intersection of a cognitive and socio-cultural perspective.