Interdisciplinary Teaching as Inter-Cultural Research

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In college, much scientific instruction occurs across disciplinary boundaries. But disciplines create their own distinct culture: conventions, goals, expectations, and epistemologies. If we treat disciplines as different cultures, cross-disciplinary instruction looks different. Probing another culture is not as simple as making an "objective" physical measurement. When measuring another culture, we bring a powerful measuring instrument – our personal intuitions and culture – that may distort or misinterpret what we see. In doing research into other cultures, we have to not only be aware our subjects' perceptions, but also of our own inevitably biased interpretive tools.

This approach can lead to deeper insights, both into the culture we are observing and into our own. For the past 7 years, we have been developing an introductory physics course for life science majors – NEXUS/Physics (N/Φ). We have tried to learn as much as we could about the culture of biology as a science, and we have learned much, both about the culture of biological science and about our own culture of physics. What we have learned has powerful implications and encourages us to make significant changes in how we present physics for life science students.

1. The basics

Constructivism: People learn new things by building on what they know.

- If we want to understand our students' learning (and lack of it), we need to understand how constructivism works.
- In STEM, we want our students to achieve "deep learning" -- not just parroting answers by rote or running algorithms without thinking.

Making meaning, making sense: What does it mean to understand?

- Meaning making arises from complex links to multiple knowledge learned in many ways. (Encyclopedic knowledge.)[1]
- What links are made and what knowledge is used to make meaning depend on the individual's social and physical knowledge and on the their interpretation of their situation: ***culture and context***.
  - Perception of the social situation — framing[2]
  - Perception and knowledge of the physical context — p-prims,[3] external representations,[4] and manipulables[5].

Culture: What do we use to interpret context?

- Culture is what we learn from experience that lets us make sense of context.
- Culture belongs to individuals and depends on our experience with social groups and situations — family, peers, media, language.
  - These factors strongly affect how we interpret and interact with the world and people around us.[6]
- Individuals can have multiple cultures that they activate under different circumstances.[7]
- As a result of our similarities — our common humanity of experience and structure, we can communicate.
- As a result of the differences in our experiences (and language), we can miscommunicate.

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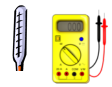
2. Exploring another's culture

Physical and ethnographic measurements don't have the same structure.



- ***Physical measurements*** — A physical measurement uses one object (the measuring device) to interact with another object to yield a measurement. Usually, both the measuring device and its interaction with the measured object are well understood.
- ***Cultural measurements*** — An observer observes or interacts with someone. The measuring instrument in this case is the observer's culture that they use to interpret the observations. But much of that measuring instrument is tacit and may not be appreciated or understood.

We understand others through our common experience and humanity. We misunderstand others when we are unaware of our cultural differences.

- When we communicate, we are always translating, inferring the speaker's meaning from language (and body language, gestures, intonation...). But our associations and interpretations are cultural and dependent on <u>our</u> perception of the context. If our subject brings a different culture or interpretation of the context than we do, we can have serious mistranslations.
- "There are two ways of looking at differences between you and someone else. One way is to figure out that the differences are the tip of the iceberg, the signal that two different systems are at work. Another way is to notice all the other things that the other person lacks when compared to you, the so-called *deficit theory* approach."[8]

Two ethnographic research paradigms make a start, but don't go far enough.

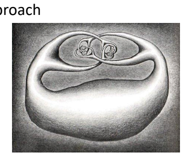
- ***Grounded theory*** calls for extensive data and observation, but assumes that the cultural analysis tools the researcher brings are perfect. If there is a reasonably good coherence between the cultures of the researcher and the subject, this can work. Otherwise, it is a recipe for missing what may be important elements.
- ***Phenomenography***[9] emphasizes the perception of the subject and that because the researchers are viewing the subjects through the lens of their own culture and intuition, that the subject's "true" perception may be missed. But it does not provide tools to get around the danger of treating the researcher's own unconsidered perceptions as the correct interpretation of another's reality.

A balanced model for ethnographic research

Hypothesis: There are significant cultural differences between how a physics instructor frames an introductory physics class and how a life sciences major frames the same class, especially the role of mathematics and epistemology.

Conjecture: The cultural differences in this case are sufficiently strong and there is a strong temptation among physics instructors to treat these differences with a deficit theory. Only by treating research into these issues as an interaction between two distinct cultures — the student's and the instructor's — can we make sense of what's going on.

A way forward: Following Agar,[8] we propose that an appropriate research (and teaching) paradigm assumes we can make much progress building on our similarities; but when we find an unexplained difficulty — a ***rich point***, we don't default to a deficit model. We put our own culture and assumptions under scrutiny. This creates a more balanced approach between researcher and subject.



*"When you encounter differences, when you experience culture, some connections are fairly simple to find. Others, in contrast, are striking in their difficulty….I need a name for this location, this Whorfian cliff, this particular place in one languaculture that makes it so difficult to connect with another. I'll call it rich… The **rich points** in a languaculture you encounter are relative to the one you brought with you….If you hit a rich point, think you've solved it, and haven't changed [yourself], then you haven't got it right."*[8]

3. Interdisciplinary teaching as inter-cultural exploration: math use in physics and biology

Are different scientific disciplines sufficiently distinct to be considered different cultures?

- Although many epistemological resources / scientific competencies (especially mathematical ones) are used by professionals in both physics and biology, the path to developing those resources is very different in the two disciplines.[10,11]
- In physics, mathematical resources are introduced early in a student's development (in high school and for all students) and are considered part of the core learning of any physicist.
- In biology, significant mathematical reasoning is rare until upper division classes and at the introductory level may be restricted to particular sub-topics such as genetics and biochemistry.
- As a result, there are potentially important cultural differences in the attitude and expectations of biology students and physics instructors in a physics class for biology students. (Box 1 on right)

NEXUS/Physics built a new introductory physics course for life science students based on extensive ethnographic research into the cultures of the disciplines.

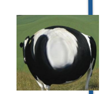
This course was designed through extensive negotiation between biologists and physicists (with input from chemists, mathematicians, and education specialists).[12]

For the first two years, the course was taught to small groups of volunteers (N ~ 20) in an interactive environment that let us explore student responses to our materials and presentation. We recorded all classes and did many informative interviews.[13]

In addition, being forced to listen carefully to students in class led the instructor to find rich points — some of which led to new insights into his own tacit cultural assumptions.

We learned that mid-college biology students favored dramatically different epistemological resources than physics instructors did. (See box 1.) In particular:

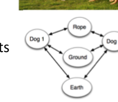
- Biology students (and biology faculty!) were uncomfortable with (even dismissive of) the "toy models" used often and without explanation in introductory physics classes.



As a result, we introduced the concept of modeling early and continually analyzed the assumptions being made and the reasons for them.

- Biology students were uncomfortable with abstractions and wanted to focus on real world situations.

As a result, we frequently imbedded our examples in real-world situations and encouraged our students to think about our examples that way. (Models and System Schema)



Box 1: Epistemological resources preferentially favored by biology students and physics instructors.

Common

S1: Physical intuition — Knowledge constructed from experience and perception is trustworthy.
S2: By trusted authority — Information from an authoritative source is reliable.

Mid-college Biology Students

B1: Learning a large vocabulary is useful — Many distinct components of organisms need to be identified.
B2: Categorization and classification — Comparison of related organisms yields insights.
B3: Life is complex (system thinking) — Living organisms require multiple related processes to maintain life.
B4: Heuristics — There are broad general principles that govern multiple situations.
B5: Teleology justifies mechanism — The historical fact of natural selection leads to strong structure-function relationships in living organisms.

Introductory Physics Instructors

P1: Calculation can be trusted — Algorithmic computational steps lead to a trustable result.
P2: Thinking with mathematics — A mathematical symbolic representation faithfully characterizes some features of the physical or geometric system it is intended to represent.
P3: Mathematical consistency — Mathematics and mathematical manipulations have a regularity and reliability and are consistent across different situations. (If the math is the same, the analogy is good.)
P4: Value of toy models — Highly simplified examples can yield insight into complex mathematical relationships.

4. A rich point from N/Φ

The instructor's tale:

"Although I was pretty well used to discussing models and assumptions in the class, when I got to electric potential, I got a bit of a shock. I presented the problem of the electric potential of two parallel plates [Box 2] as a clicker question. We had gone over the electric field in the case of two oppositely-charged infinite plates, and the question was supposed to help them connect electric field and electric potential.

About half the students gave the correct answer (C or I), but two objected. One argued any curve should have spikes as you passed through the plate since you would get close to an ion. A second argued that the potential curve had to be zero along the center of the plates since whatever charge you found contributing to the potential on one plate, there would be a matching and opposite one an equal distance away on the second plate.

I liked both of these reasons and saw them as good physics! I realized that I used the example automatically without thinking, focusing only on the math in a way that undermined two basic lessons I thought I was explicitly trying to teach:

(1) *Physics is about something real. Always start from a mental image of a physical situation and refer everything back to it.*
(2) *In physics we often use simple models to illuminate core ideas. Be explicit about your assumptions – what you are paying attention to and what you are ignoring."*

Box 2: A clicker question

If two uniform sheets of equal and opposite charge can be treated as if they were infinitely large, which of the following graphs might serve as a graph of the electrostatic potential as a function of the coordinate x along the dotted line?