Resources: A Theoretical Framework for Physics Education

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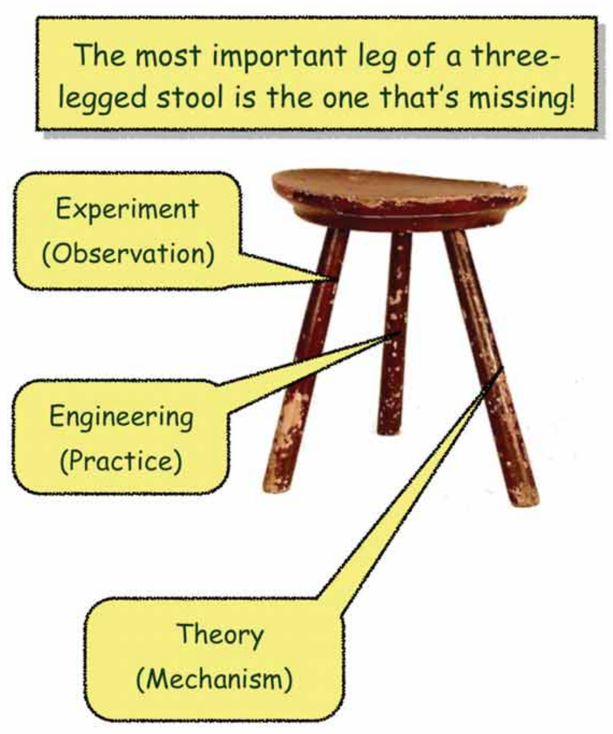
Abstract: The Resources Framework (RF) is a structure for creating phenomenological models of high-level thinking. It is based on a combination of core stable results selected from educational research phenomenology, cognitive neuroscience, and behavioral science. As a framework (as opposed to a theory), it provides ontologies -- classes of structural elements and their behaviors -- rather than providing specific structures. These ontologies permit the creation of models that bridge existing models of knowledge and learning, such as the alternative conceptions theory and the knowledge in pieces approach, or cognitive modeling and the socio-cultural approach. Structurally, the RF is an associative network model with control structure and dynamic binding. As a phenomenological and descriptive framework, it does not (yet) create mathematical models from low-level elements. This poster outlines the RF and shows how it gives new ways of looking at traditional issues such as transfer, concepts, ontologies, and epistemology.

Why do we need a theoretical framework?

Learning and teaching a complex science such as physics are in themselves complex processes. It can take many years to learn a science or to learn to teach science effectively. If we want to improve how people both learn and teach science, how do we do it? In order to begin thinking seriously about learning and teaching, we have to have a way of thinking about it: a language, an ontology of what are relevant structures to discuss, and an epistemology of methodology and decision making. How do we decide when we know something about learning and teaching?



What should a theory do for us?

Explanatory power

We often see students saying things or behaving in ways that seem strange to us. A good theory should help us understand why they do this.

Productive modeling

A theory should give us a way of modeling classes of phenomena — not necessarily everything at once. (Think about the SE for atoms and molecules, e.g.)

Guidance for instructional design

Though the theory may not be predictive, it should be schematically so — suggesting options for instruction and things we might want to look at to test.

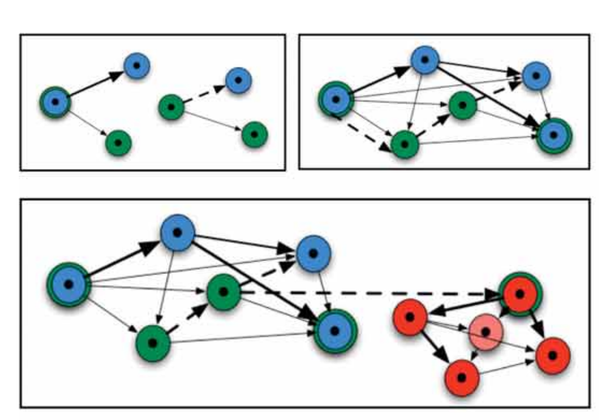
Cumulability

We ought to be able to add to the structure incrementally — learning new things that are consistent and make the entire structure stronger and more powerful.

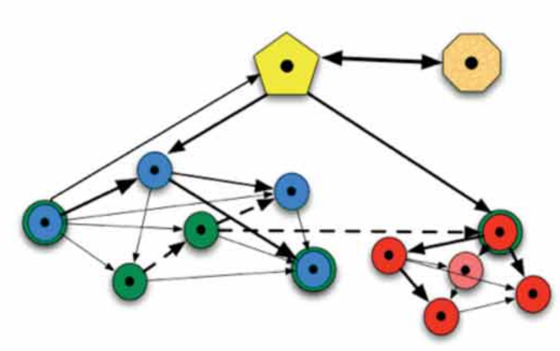
Basic Principles

The RF is an associative network model with control structure and dynamic binding. The RF is a phenomenological and descriptive framework and does not (as of yet) create mathematical models in which predictions arise from calculations with low-level elements having specified properties.

Associative network – The basic ontology of the RF is that of a network with nodes and directional connections. The activation of knowledge is thought of as the activation of clusters of linked elements, occasionally imagined as neurons. The activation of one neuron or cluster of neurons leads, through connections between neurons (synapses), to activation of other clusters. Learning is pictured at a fundamental level as the establishment of strong connections so that activation of one neuron or cluster of neurons leads inevitably to the activation of other neurons or clusters of neurons. Associations can be excitatory or inhibitory.

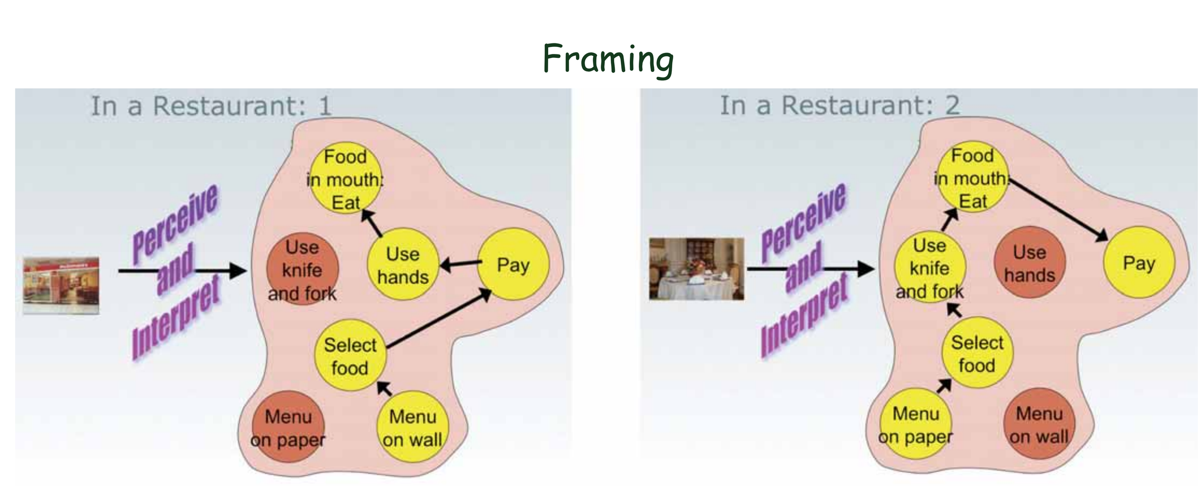


Control structures – The network of neurons in the brain is known not to be simply associative. There are structures (hippocampus, cingulate gyrus, etc., etc.) that appear to have specific purposes, just as in other parts of the body (heart, lungs, liver, etc., etc.). Control structures rely heavily not only on activating association, but on inhibition. The combination of control structures and the associative network produce he wide variety of learning and thinking behaviors we observe.



Some examples of control structures include:

- Selective Attention
- Context Dependence
- Framing
- Epistemology
- Metacognition



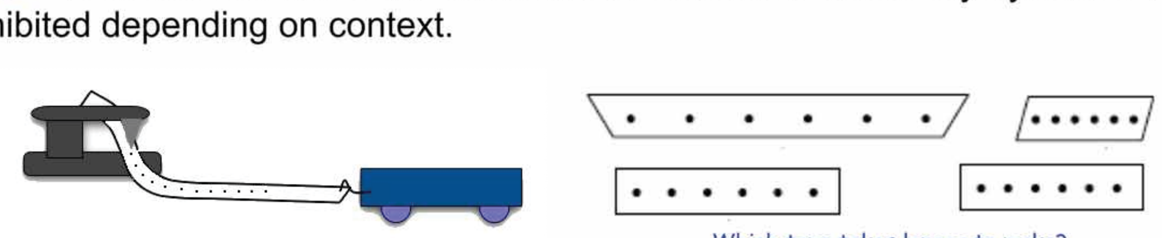
Binding – Clusters of neurons that activate together frequently become strongly tied so that they always activate together. This makes possible the creation of networks of higher level structures – concepts, p-prims, or schemas – that the user perceives as unitary. Binding can occur at many levels from being extremely tight to being rather loose. Both basic associations (concepts) and control structures (framings) can be tightly or loosely bound.

CAT

It is hard to see the word "cat" and not to imagine its referent

One can perceive an orchestral performance as unitary or listen for individual instruments or motifs.

Dynamic – A critical element of the entire model is that it is extremely dynamic. Associations are activated and inhibited depending on context.



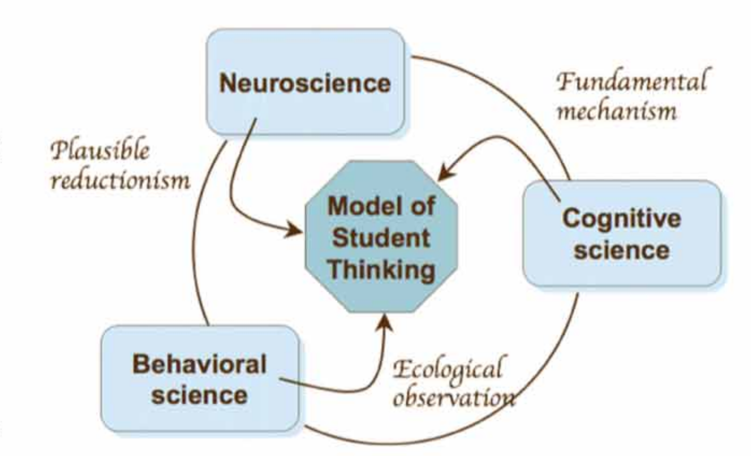
A cart pulls a paper tape through a machine that taps at a fixed rate creating dots. When asked to sort the tapes based on how long they took to make, many students respond, "longer tapes take longer." When asked how fast the carts are traveling, students can quickly shift their reasoning to see that the tapes take the same time but that longer means the car it going faster. (Frank)

The Resource Framework: Preamble

The Resource Framework (RF) is a structure for creating phenomenological models of high-level thinking. It is a framework rather than a theory in that it provides ontologies – classes of structural elements and the way they behave – rather than specific structures. As such, it provides a framework that permits the creation of models that bridge many existing models such as the alternative conceptions theory and the knowledge in pieces approach or cognitive modeling with the socio-cultural approach.

Origins, Uses, and Scope

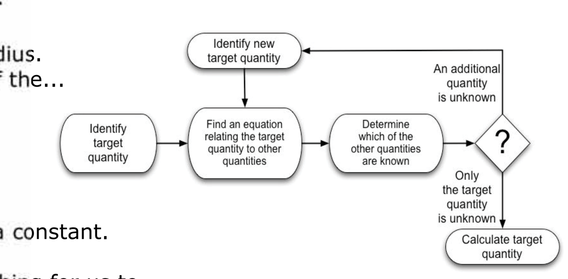
The RF is based on a combination of core stable results selected from educational research phenomenology, cognitive and neuroscience, and behavioral science. Results from these fields offer new insights and help us structure our theoretical development in a way that is consistent with the emerging unified theory of cognition and behavior. Research using the RF focuses often on issues of learning physics, but the framework is applicable to a broader range of topics.



Student Reasoning

Estimate the difference in pressure between the floor and the ceiling in your dorm room. (Note: You may take the density of air to be about 1 kg/m³.)

Martha: We're saying that the pressure...
Susannah: Right.
Martha: Well pressure's supposed to be higher at the bottom, isn't it?
Susannah: Hmm?
Martha: Pressure is supposed to be higher at the bottom.
Susannah: I think there's more at the bottom, because the thing, because the gravitation.
Martha: And, there's pressure pushing down on it.
Susannah: Um-huh.
Martha: OK.
Susannah: Pressure's equal to the radius times the moles of the gas times the temperature divided by the volume. So, what we need to do, we know the pressure find the volume from this. Density is equal to...
Martha: Are you using pV equals nRT?
Susannah: Huh?
Martha: Are you using pV equals nRT?
Susannah: Yeah, or yeah.
Martha: Or.
Susannah: Or p equals R times nT...
Martha: Over V.
Susannah: Over V
Susannah: OK. So, if let's say it's [the density] equal to mass over volume, then [to another student] yeah. No I just found the formula to do it. So, this is equal to mass over volume, then the mass is equal to... So, basically we just found the formula that p is equal to the radius times the moles times the temperature over the volume. So, if we have the density we can find the volume.
Martha: Is R the radius?
Daphne: I don't think R is the radius.
Susannah: It's not? The radius of the...
Martha: R isn't radius. R is...
Susannah: Or, whatever R is.
Daphne: Some number.
Martha: It's not radius.
Susannah: Is it a constant?
Alice: Yeah, it's a constant. It's a constant.
Martha: It's a constant. It's...
Susannah: Awesome. One less thing for us to find



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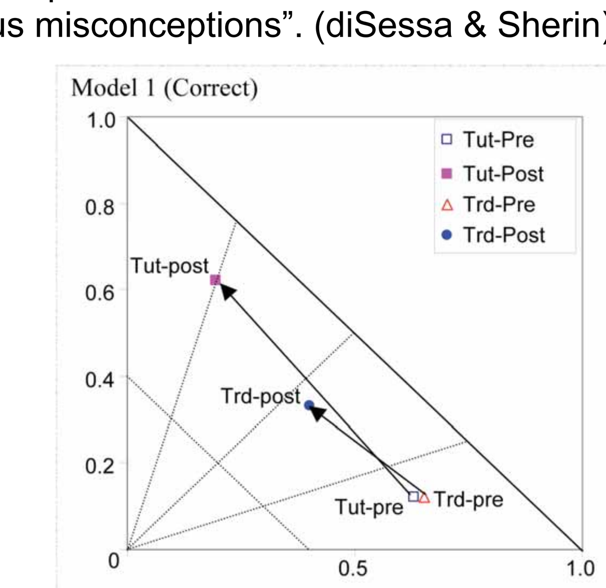
What does the RF do for a researcher?

1. Understanding the common resources that students apply can help the researcher make sense of student errors that seem, at best, bizarre, or at worst "dangerous misconceptions". (diSessa & Sherin)

2. The emphasis of the RF on the dynamic nature of cognition reminds us that students may not have a single fixed response to a given issue. This implies that changing answer choices on clusters of equivalent questions can be meaningful and informative. (Bao & Redish)

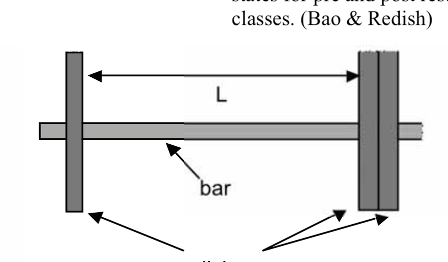
3. Since inconsistencies are expected in the RF, it is important to NOT throw away items that are unexpectedly poorly correlated as "invalid". (RSS, Elby)

4. Knowing the kind of resources that are commonly employed, the RF can help researchers design follow-up questions that show the plasticity of a student's response. (Sayre&Wittmann)



Model plot of student class model states on Force-Motion with FCI data from University of Maryland. The two arrows represent the shifts of the first model states for pre and post results of Tutorial and traditional classes. (Bao & Redish)

The bat balances as shown. How do the masses on either side of the finger compare?



Where would you pick up this barbell so it balanced given that the bar is light compared to the disks?

Researchers found that students thought that when a bat was cut at its balance point, it would have equal masses on both sides. They interpreted this as a misconception about the center of mass and created a lesson based on this assumption. But when the students are asked where to pick up the barbell so it balances, they get it right.

What does the RF do for a teacher?

1. The RF encourages teachers to not view student errors as something "to be expunged" but a something that gives insight into a student's thinking; this can help build an understanding of what the student is bringing to the table and what the student has with which to construct her knowledge.

2. A teacher who views student thinking through an RF lens is more likely to focus on broad issues of learning -- learning to learn, metacognition, and whether the student is developing a good toolkit.

3. The RF helps teachers understand possible dangers of certain "successful" instructional tools (e.g., epistemological side effects from instruction using cognitive conflict).

4. Student thinking displays both a lability (switching from one answer to a contradictory one quickly and easily) and a stability (refusing to give something up despite growing negative evidence). The RF gives teachers a language to describe these phenomena conveniently.

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