(Draw your physics homework?) Art as a path to Understanding in Physics

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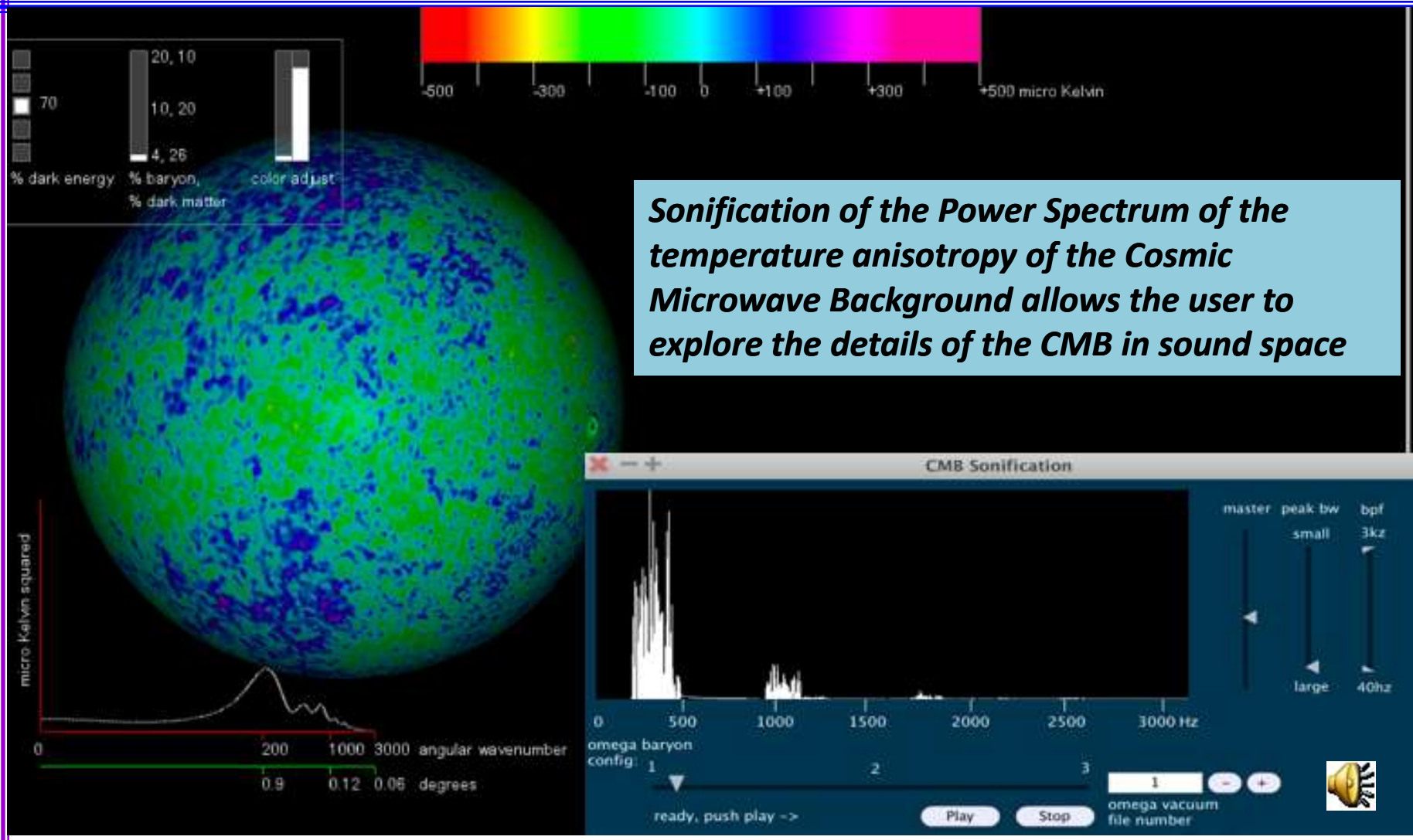
Arts & Science Collaborations in the AlloSphere at U.C. Santa Barbara

Founder / director / inventor:
Professor JoAnn Kuchera-Morin

Movie inside the AlloSphere at UCSB
see
http://www.allosphere.ucsb.edu/media.php

See www.allosphere.ucsb.edu

Visualization & Sonification of the CMB



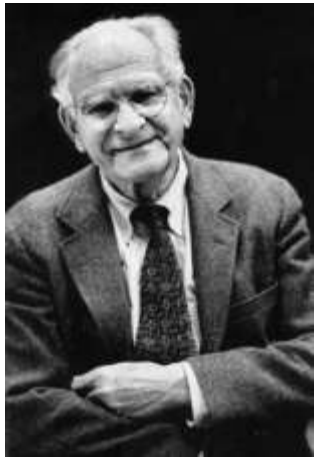
Sonification of the Power Spectrum of the temperature anisotropy of the Cosmic Microwave Background allows the user to explore the details of the CMB in sound space

PI: Jatila van der Veen

Collaborators: Philip Lubin, JoAnn Kuchera-Morin, Matthew Wright

Graduate Students: Ryan McGee, Basak Alper, R.J. Duran,

A Societal Problem : Persistent fear of Physics and Math



"Why is physics as a science considered 'inhuman' by so many people, including some of the students we teach?" (Victor Weisskopf, 1976)

What's your opinion?

A. **Too much math**
B. **Too hard and confusing**
C. **Very dry and boring**
D. **Teacher / professor was terrible at explaining it**

(paraprased from real people's postings on the internet)

The Problem : Persistent fear of Physics and Math

I was just actually talking with my parents about this yesterday, how sad it is that so many people are – in a way – conditioned – or - very Aldous Huxley, but um – that children grow up learning that science is scary and – especially physics and math. Somehow, chemistry doesn't even have that big of a stigma, but physics and math – it's like, Oooo, Scary – and especially, I think it gets communicated especially to girls still…

-female sculpture major, College of Creative Studies, 2007

Email from a junior high physical science teacher:

Please allow me to introduce myself. My name is *<removed>.* I have been a special education teacher for several years, and am finding my recent assignment a bit challenging.

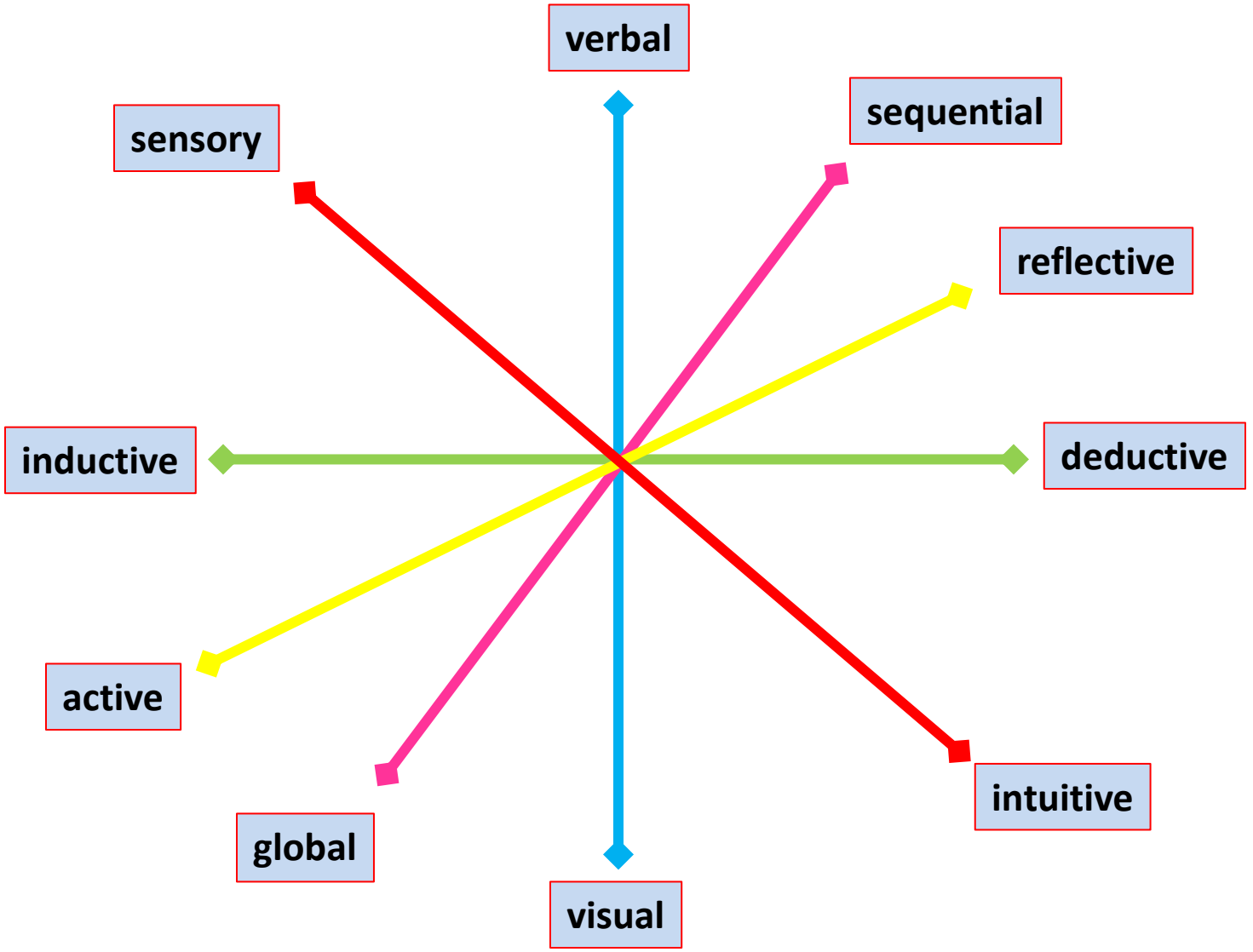
I am co-teaching Conceptual Physics this year - and I am finding both the course and the textbook to be very "male centered", for lack of a better word. I know there are many young women in our community who enjoy athletics. However, if I have to read/view/listen to another explanation of the relationship between Physics and any ball-throwing sport I may lose my patience. I can only imagine how the students in class who are not interested in popular athletic programs feel at this point.

What's your opinion?

A. Agree / relate to this teacher's frustration
B. Disagree
C. No opinion

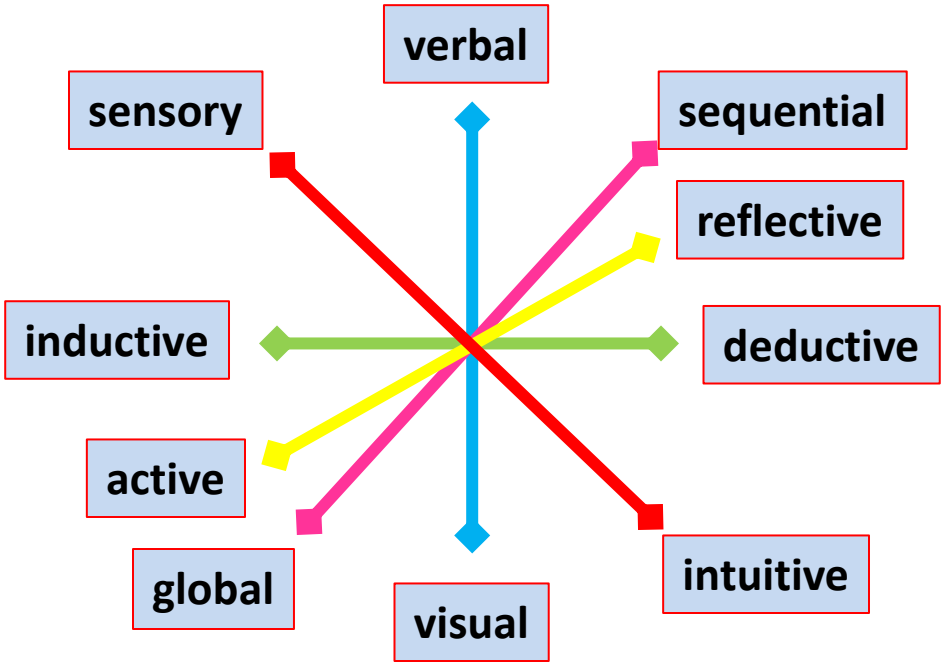
Mismatch between learning preferences and teaching styles?

Felder and Silverman's (1998) Learning Style Model:



What's your learning style?

A. verbal-sequential-reflective-deductive-intuitive
B. visual-global-active-inductive-sensory
C. combination, but more A than B
D. combination, but more B than A



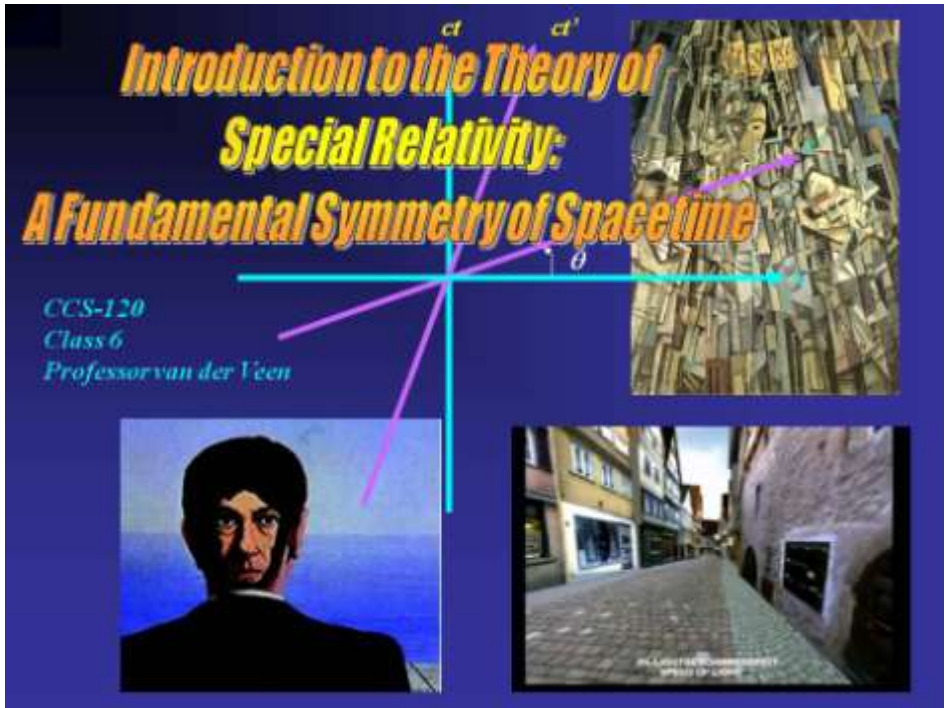
What do you think is the learning style of most of your students?

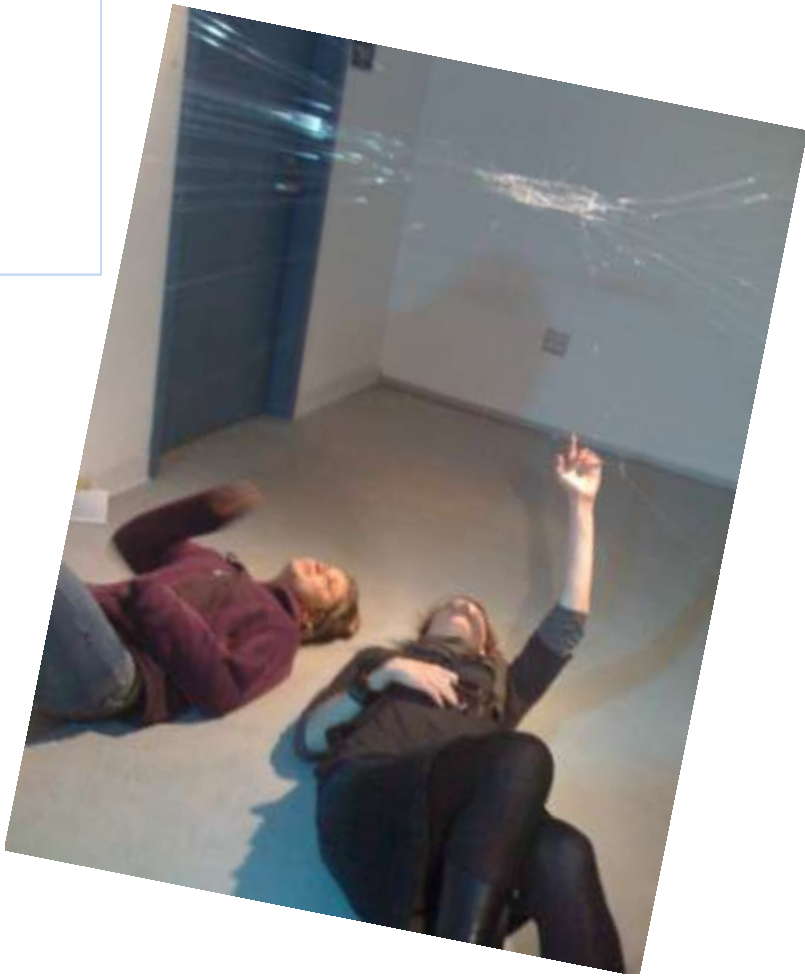
Why do so many people hate physics?

The Intervention:

Arts-based practice in physics and math education

My premise:
Through arts-based teaching practices it is possible to make tangible the connections between math *as a language of nature* and the physical universe we seek to describe.

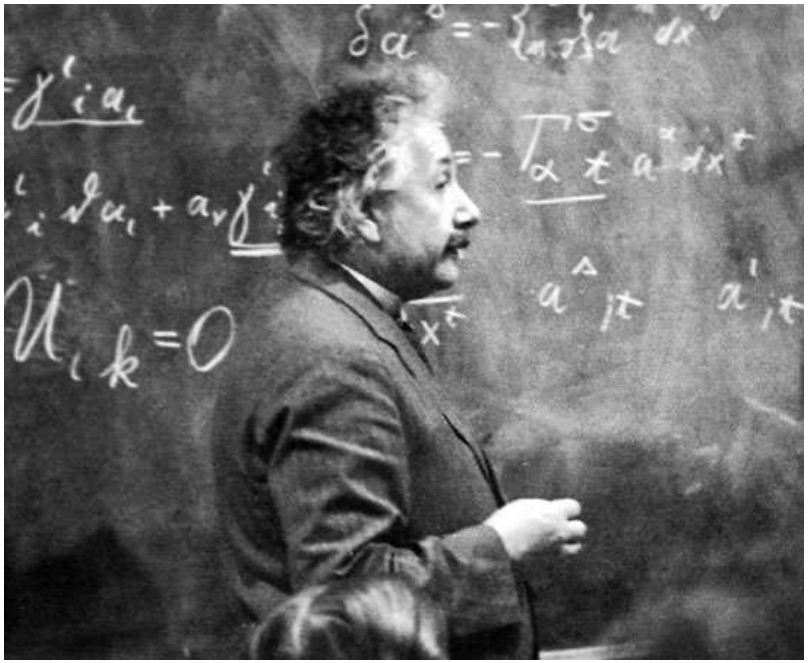




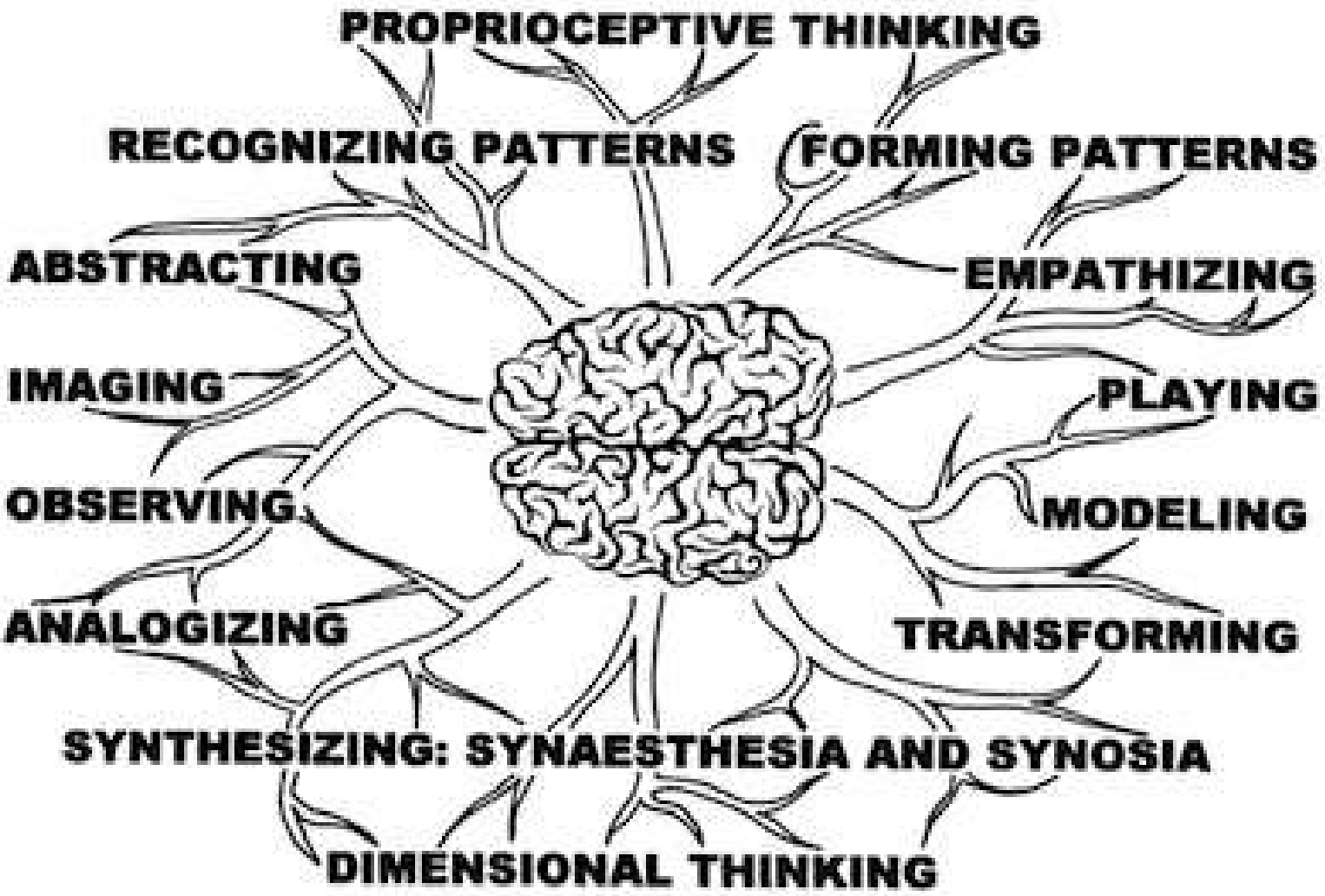
Blend the artist's and scientist's ways of knowing

"…arts and sciences are, indeed, similar enough that the methods of one can usefully be employed to make breakthroughs in the other." Robert Scott Root-Bernstein,
Source: http://artworks.arts.gov/?tag=robert-root-bernstein

"The physical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be voluntarily reproduced or combined."
Source: a letter from Einstein to mathematician Jacques Hadamard in 1945



The ways of knowing of arts and science are blended in the brain



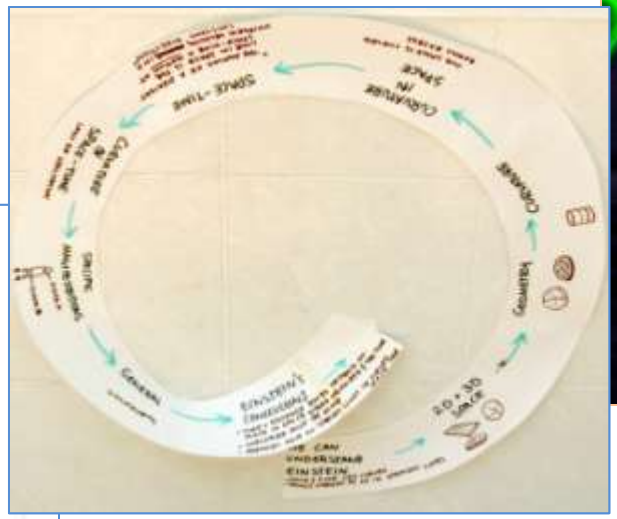
Source: http://artworks.arts.gov/?tag=robert-root-bernstein

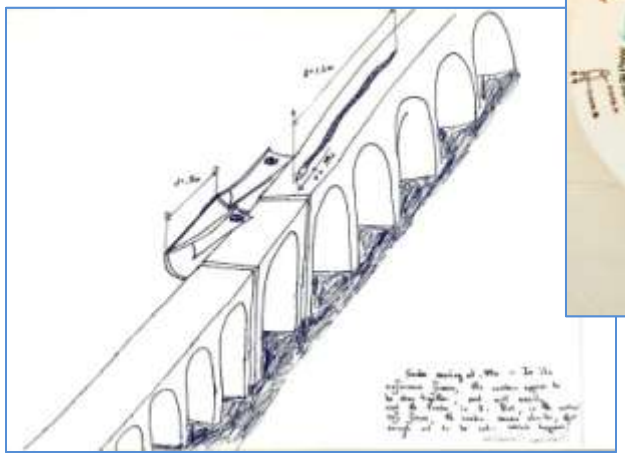
New Visions in Science Education:

AESTHETIC PHYSICS EDUCATION

SYMMETRY AND AESTHETICS IN CONTEMPORARY PHYSICS

An interdisciplinary course which utilizes visualizations, drawing, and music, along with mathematics, in teaching foundations of modern physics, starting from the perspective of symmetry.





AESTHETIC PHYSICS EDUCATION

Based on Professor Maxine Greene's Model of Aesthetic Education

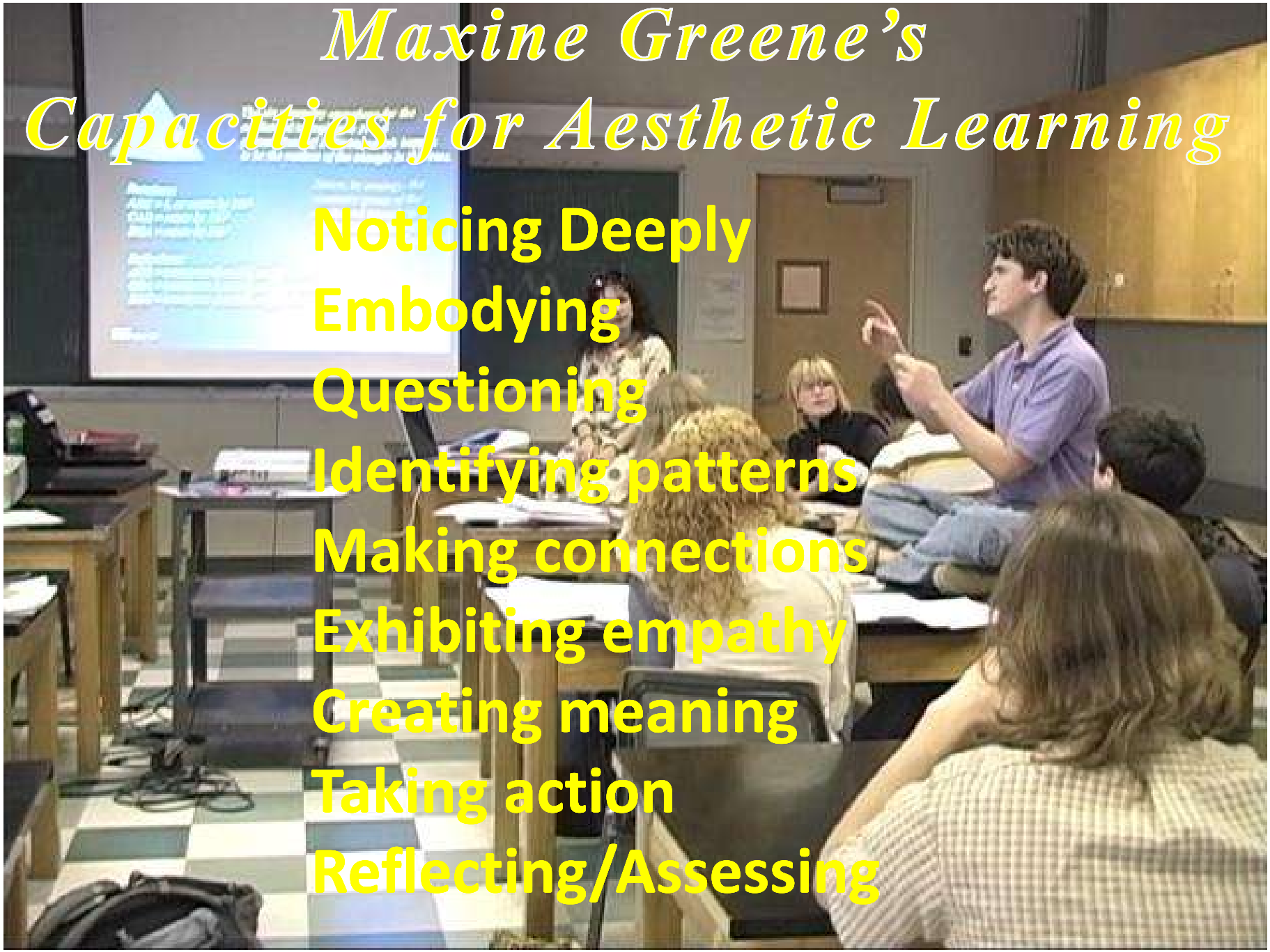
"I'm a believer in the unanswerable questions, the really hard ones."

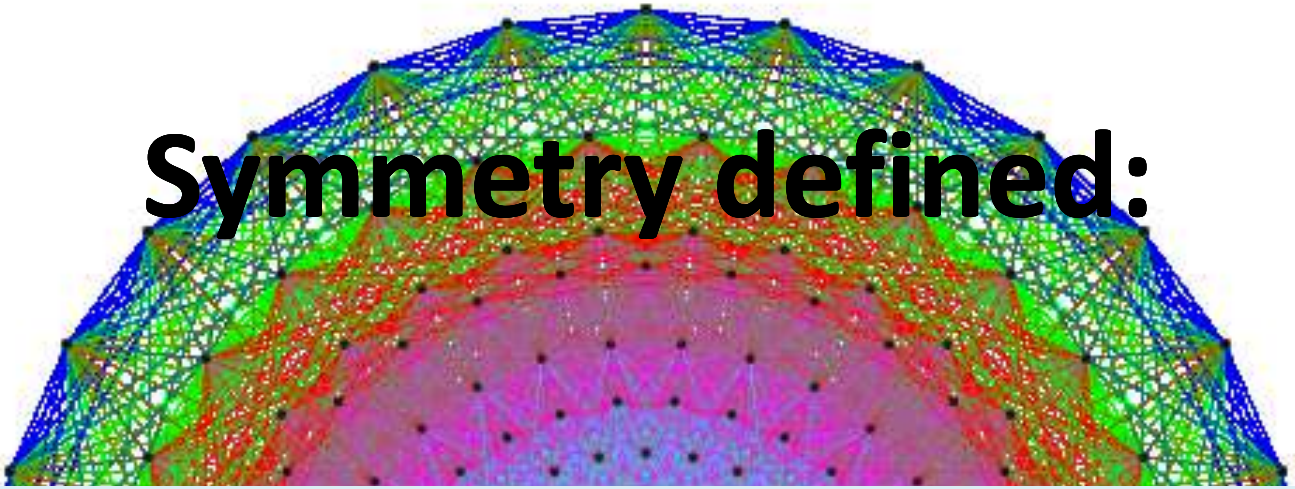
—Maxine Greene

and Noether's Principle, which is the basis of all of physics:

For every continuous symmetry in Nature, there is a conservation law in Physics.

Professor Emmy Noether
23 March 1882 – 14 April 1935


Maxine Greene's
Capacities for Aesthetic Learning
Noticing Deeply
Embodying
Questioning
Identifying patterns
Making connections
Exhibiting empathy
Creating meaning
Taking action
Reflecting/Assessing



Symmetry defined:

When you make a change in a system, *or a change in your viewpoint*, and after the change, the system looks the same as it did before.

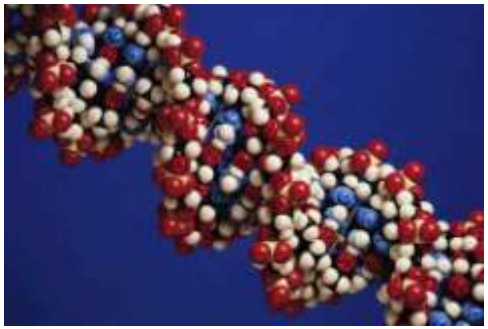
Noether's Theorem: All known laws of physics can be traced to continuous symmetries in Nature.

Symmetry in Nature :

rotational symmetry

screw symmetry = translation + rotation

translational symmetry



reflection symmetry

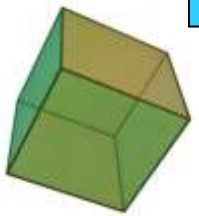
glide symmetry = translation + reflection

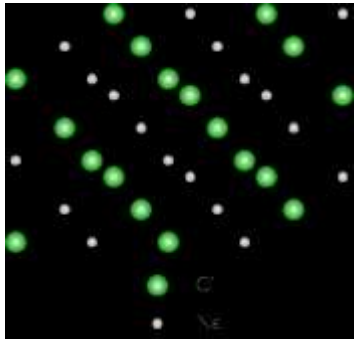
There are 3 basic types of observed symmetries in Nature, and 2 composites.

Symmetry in Nature :

Symmetry is apparent in crystal shapes in Nature, which reflect internal ordering of atomic structure...

halite (hexahedron)





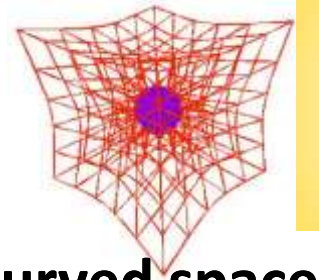
fluorite (octahedron)

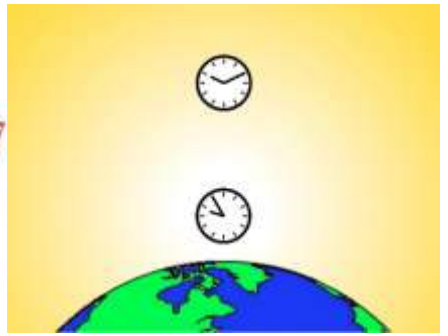
garnet (dodecahedron)

quartz (combinations)

Symmetry in Nature :

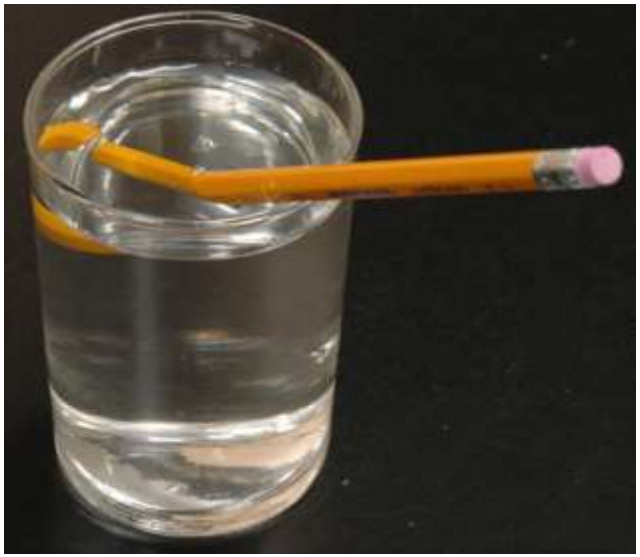
A thrown ball always follows a parabolic trajectory *from our viewpoint* due to the strong curvature of TIME close to the surface of the Earth.

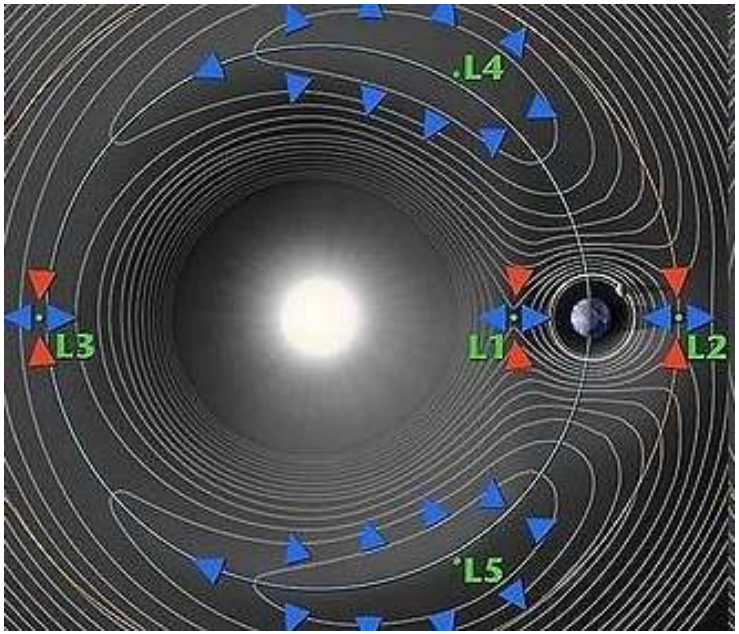




The ball always 'chooses' this shape in curved spacetime because it is the only path that conserves momentum and energy.

Symmetry in Nature :





Symmetry considerations connect the shape of soap bubbles, gravitational interactions of planets, and the bending of light when it passes from air to water and back.

Three design features of this model, applicable at any level:

1) Contemporary Perspective: *"Noether before Newton"*

Start with Symmetry, discuss Math as a Way of Knowing; Motivate physical laws with the search for patterns in nature

2) Aesthetic Approach:

Math and Art are both languages which describe nature; Math/Science and Music/Art are complementary ways of making meaning

3) Interdisciplinary Strategies:

use writing, art, music, and math; instead of tests, use project-based assessments; teach collaboratively and utilize guest speakers, and field trips to labs & galleries

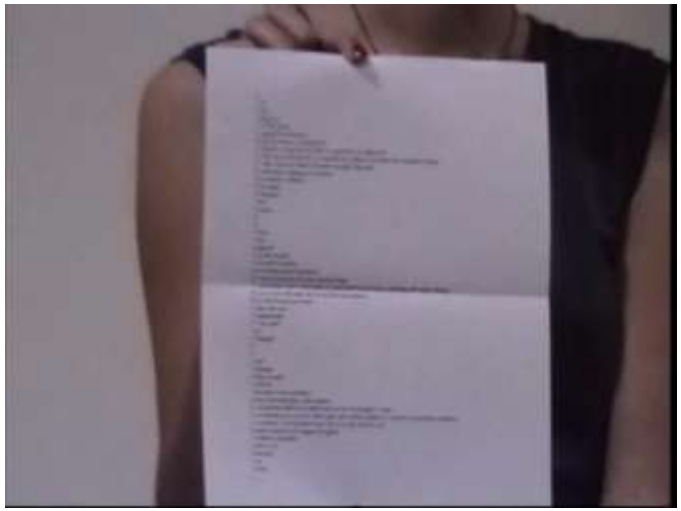
Assignments:

Weekly readings and written Reading Reflections (RR's)

Drawing/sketching / other media assignments

Symmetry demonstration and write up

Final project: Physics work of Art in any medium, with write up



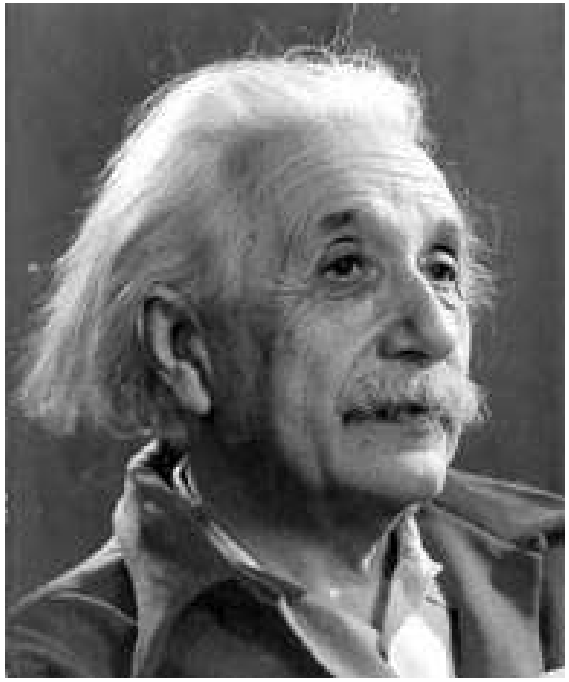
1. Fibonacci-metered poem, 2007
2. Multiverse installation, 2012

Sample Assignment: Drawing for Understanding

From Draw your Physics Homework? Art as a Path to Understanding in Physics Education, van der Veen (2012), AERJ 49(2) , pp. 356-407

First drawing assignment:

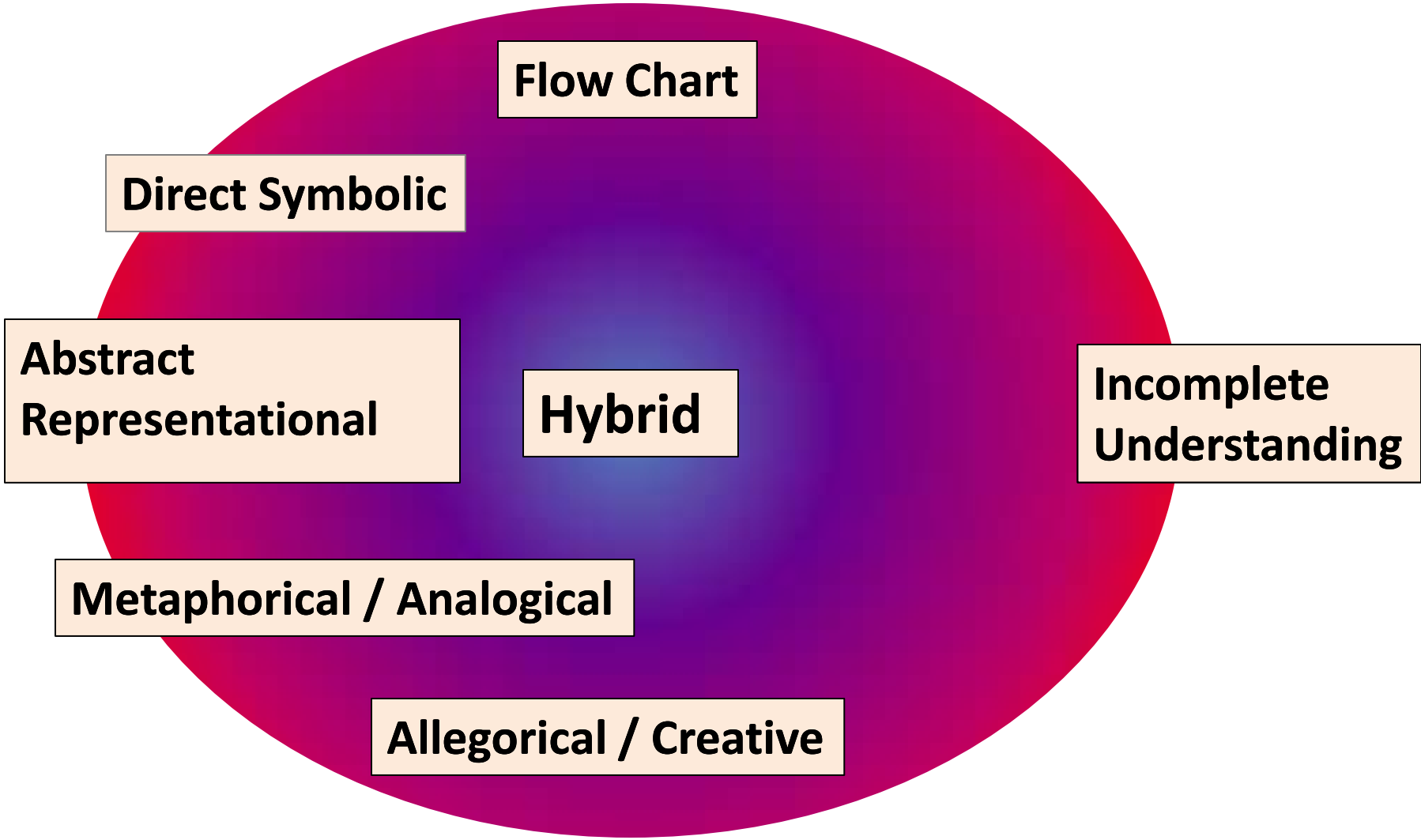
Draw your understanding of Einstein's view of the process of physics as described in his 1936 article, *Physics and Reality.*



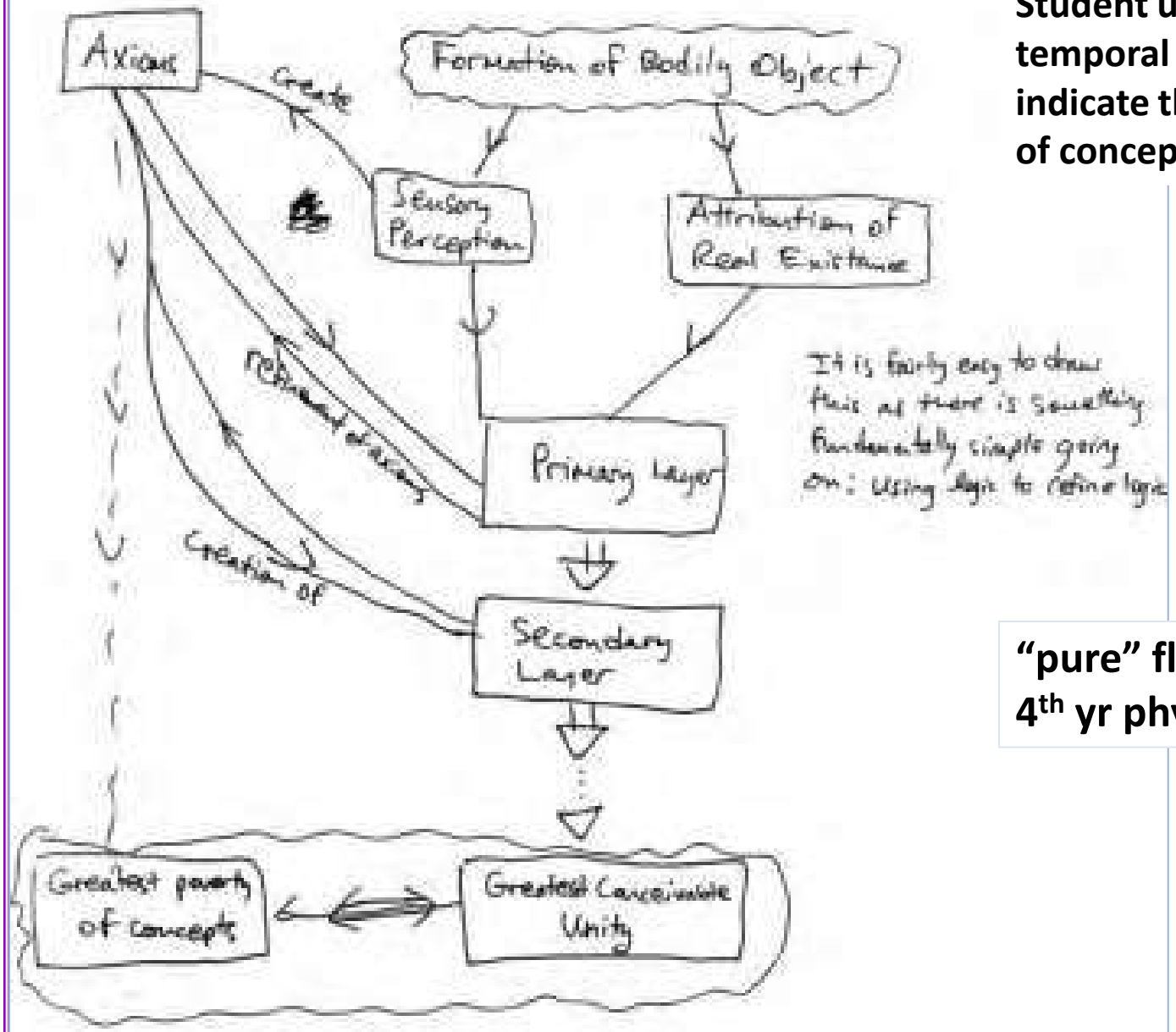
The aim of science is, on the one hand, a comprehension, as complete as possible, of the connection between the sense experiences in their totality, and, on the other hand, the accomplishment of this aim by the use of a minimum of primary concepts and relations. [Einstein (1936)]

Turn over your ABCD paper and sketch the way you visualize the process of science as described by Einstein.

I find that students' drawings tend to group loosely in 5 categories, or combinations of them



Flow charts



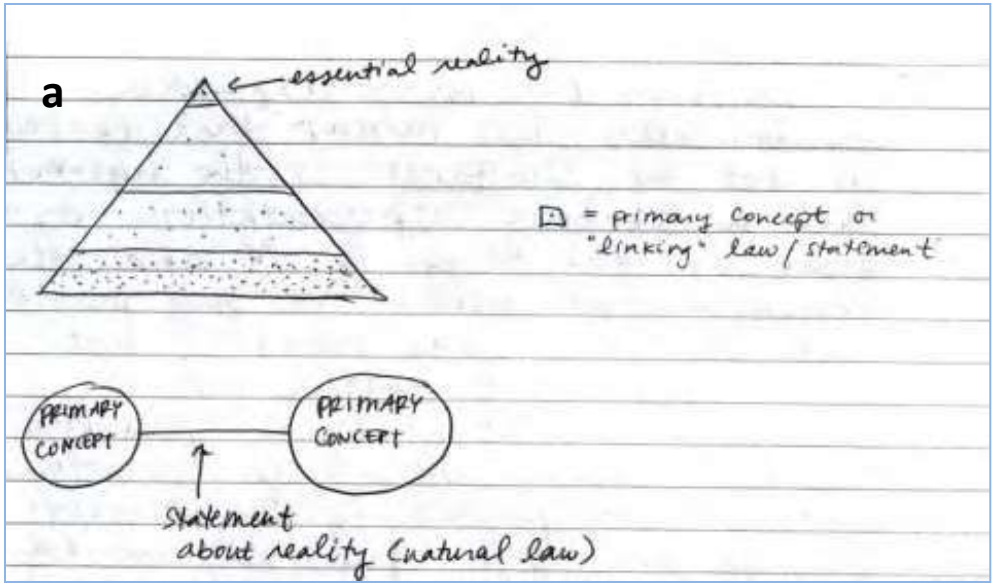
Student uses elements of temporal progression to indicate the development of concepts in the article.

"pure" flow chart
4th yr physics, M

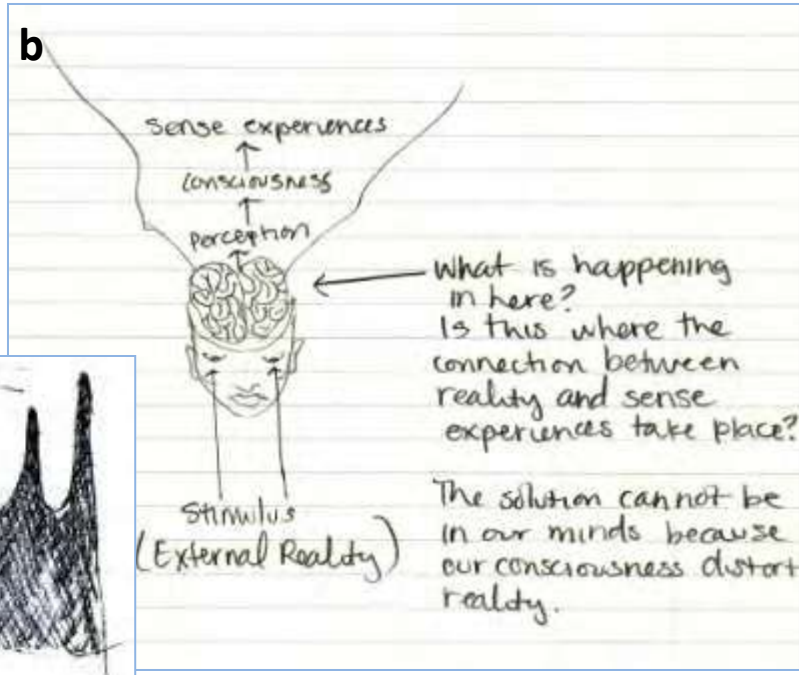
Direct Symbolic

Student uses pictures of recognizable objects to represent concepts in the article in a 1: 1 mapping.

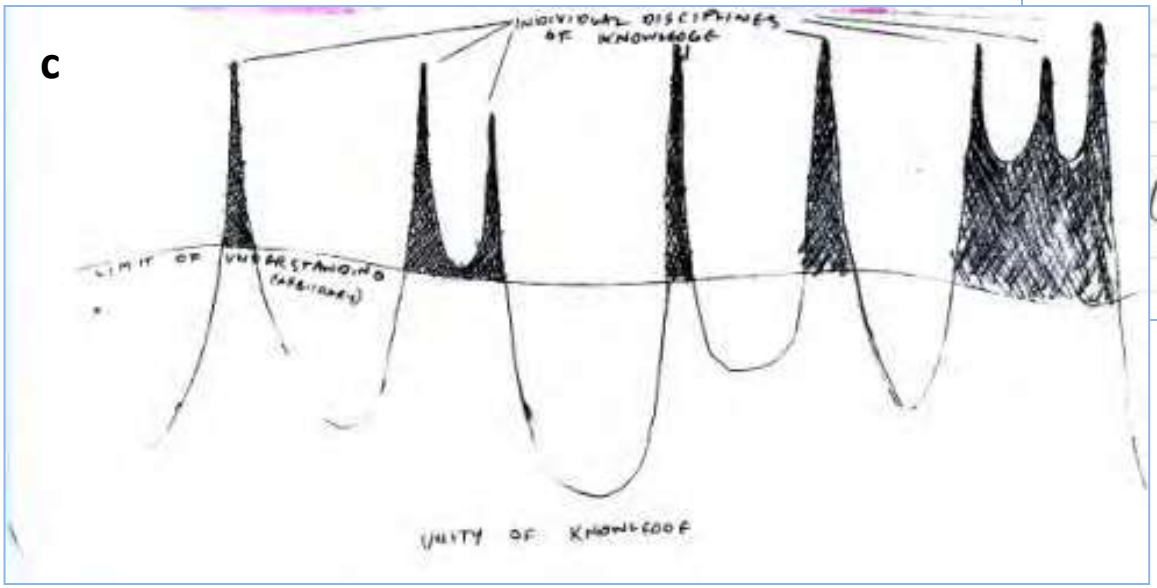
a



b



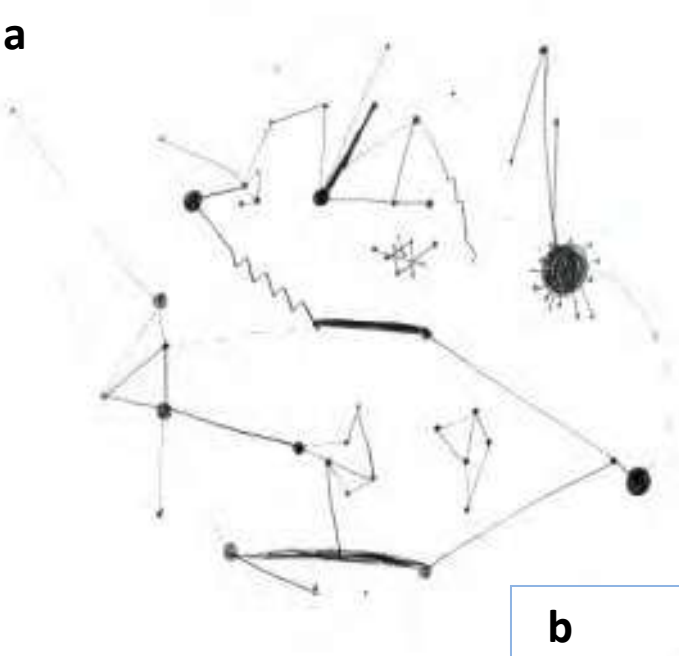
c



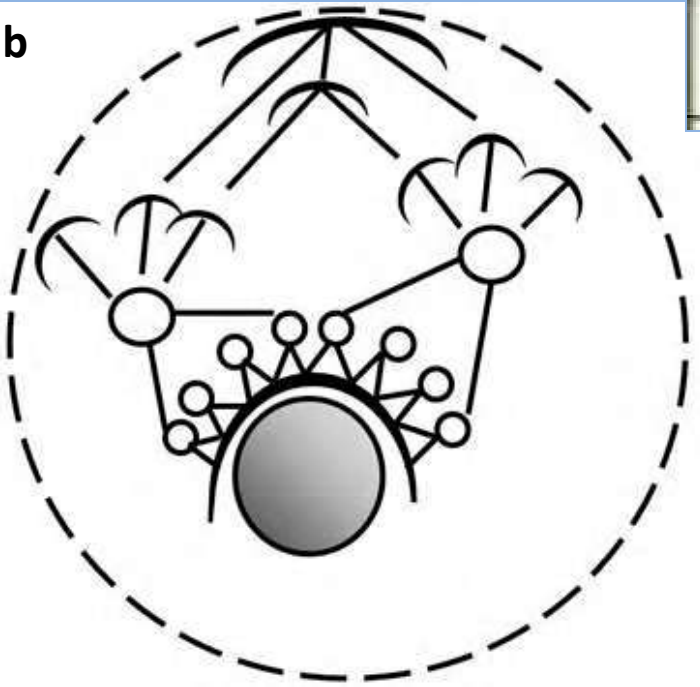
a) 1st yr, literature, F
b) b) 4th yr, neuropsych, F
c) 4th yr, geophys, M

Abstract Representational

a



b



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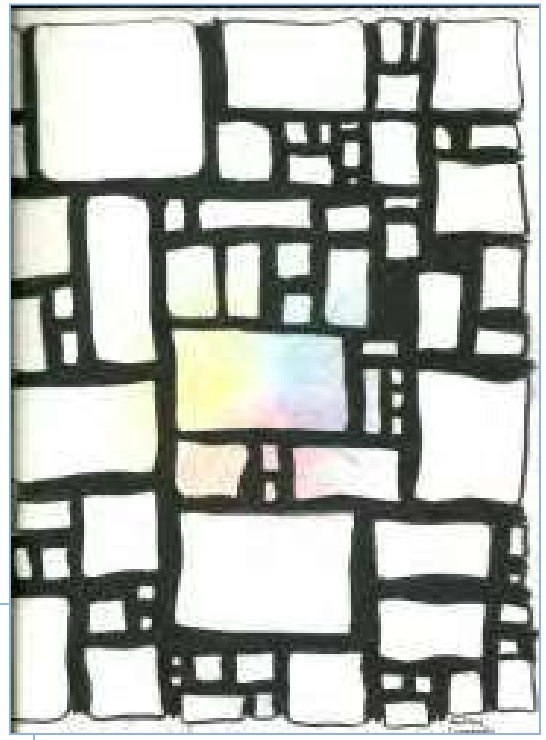


Student uses abstract symbols with a 1:1 correspondence between the symbol and the concept being represented.

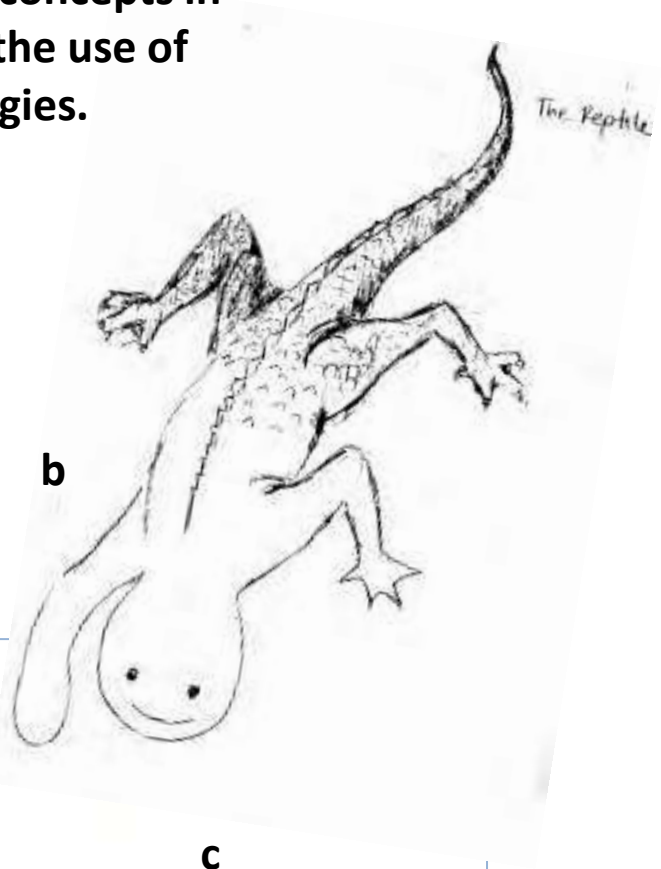
a) 1st yr physics, F
b) 1st yr math, F
c) 3rd yr math, M

Metaphoric / Analogical

Student represents concepts in the article through the use of metaphors or analogies.

a

b



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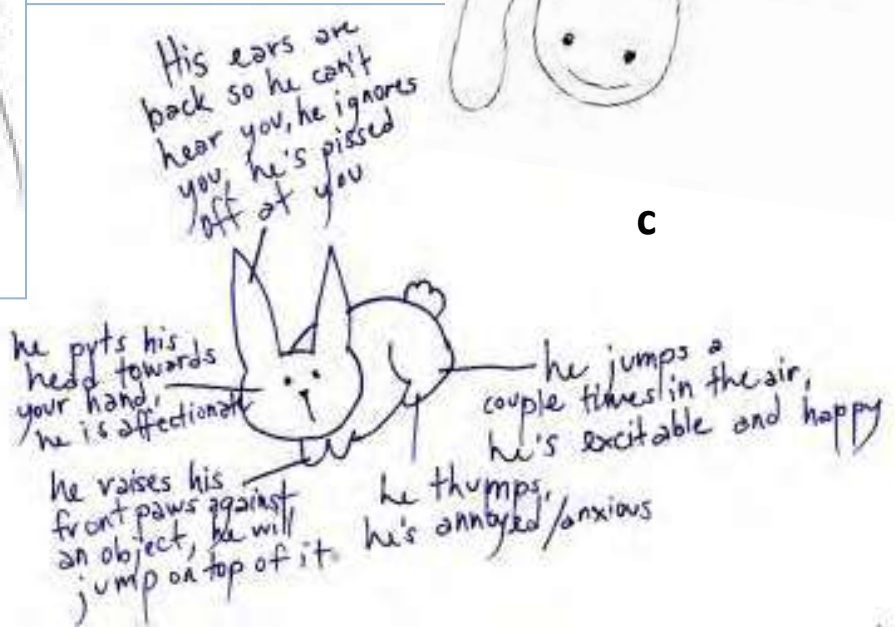
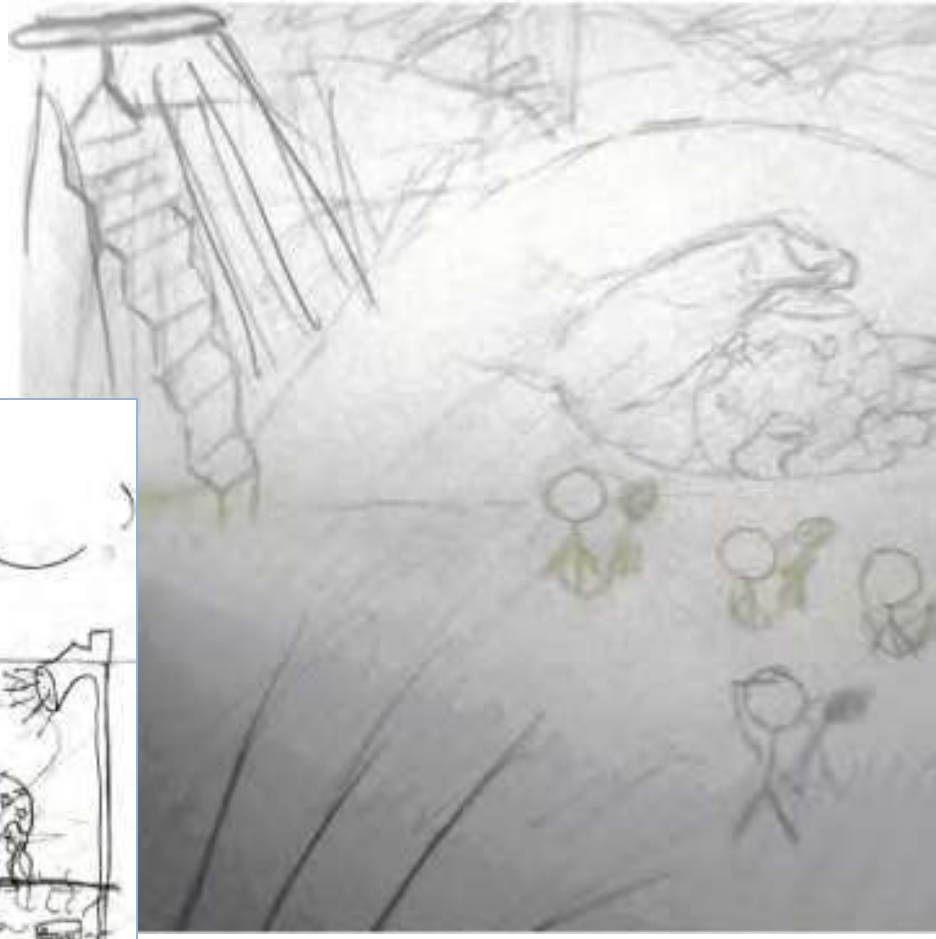


a) 1st yr. phys/math, M
b) 1st yr. math, M
c) 2nd yr. comm., F

Allegorical / Creative

Student represents the intention of the article with a pictorial story, or "what-if" scenario.

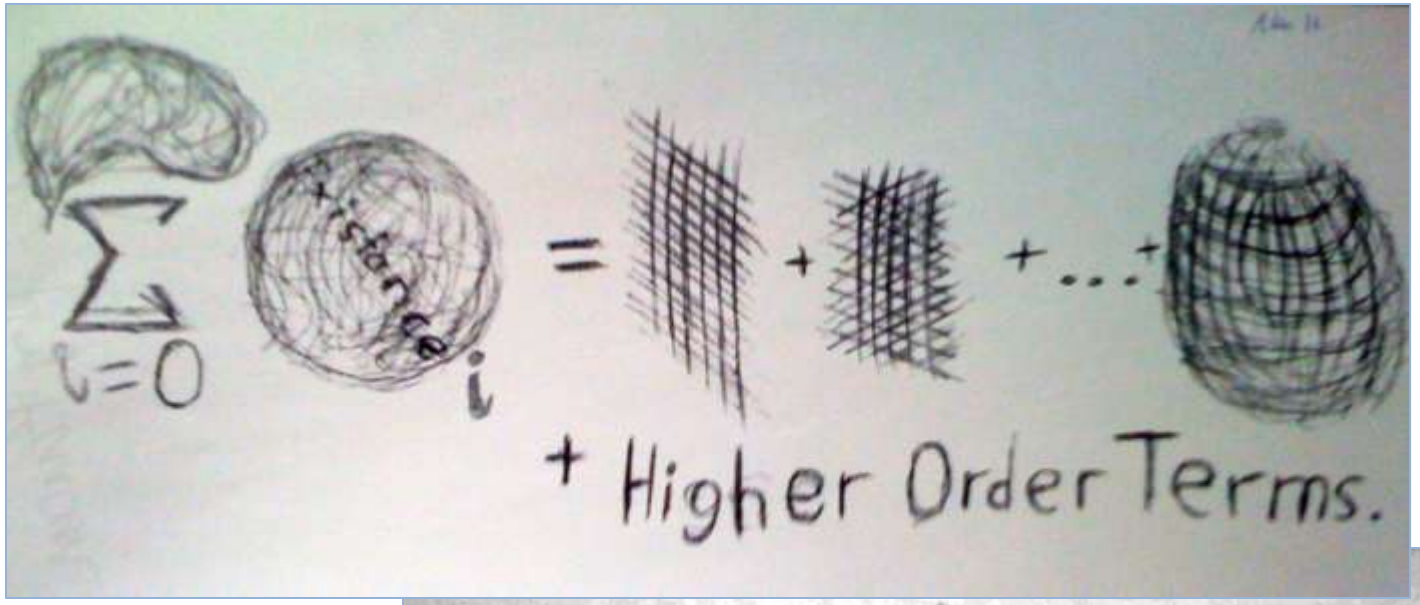
A World without Eyes
2nd yr polisci, F (musician)



Plato's Cave
1st yr physics, M

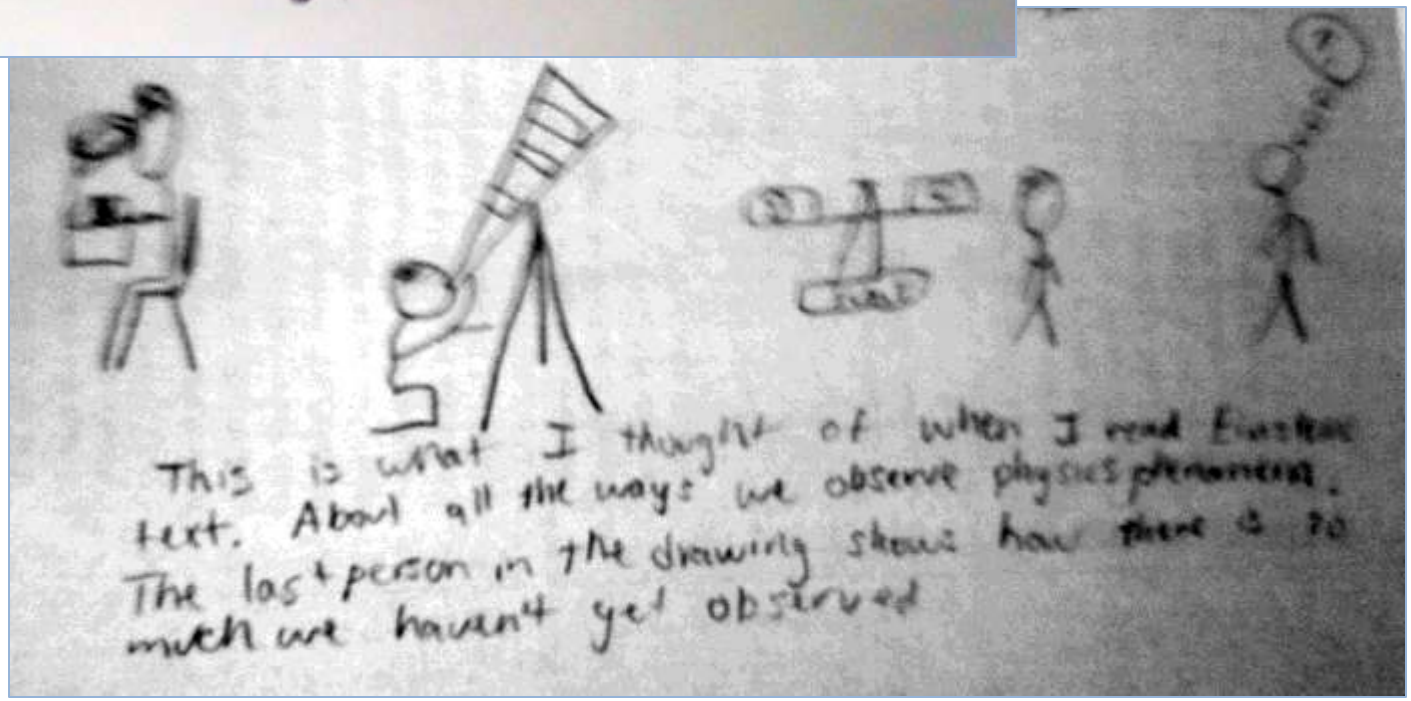
"Hybrid" Flow charts

combine pictures with an element of temporal progression

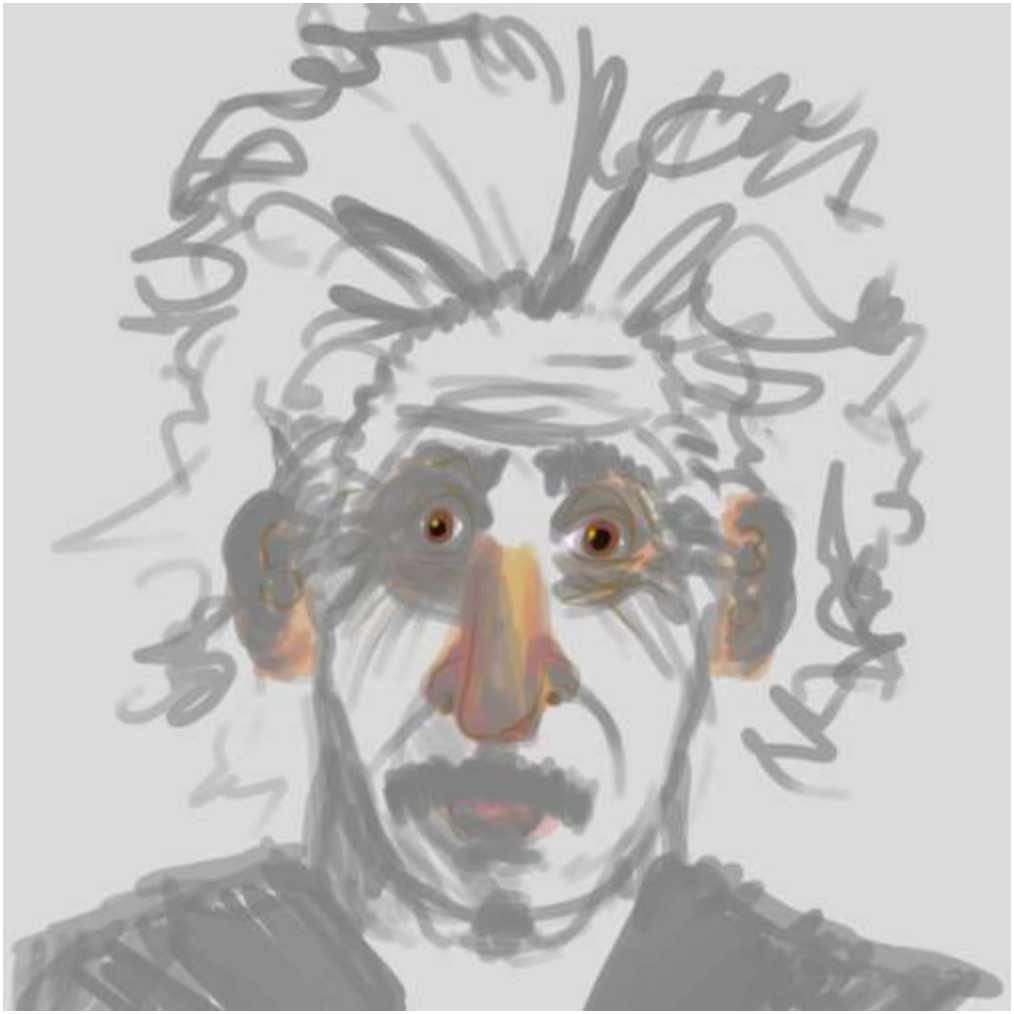


top:
1st yr physics, M

bottom:
1st yr biology, F



Incomplete understanding



second year art major, M

A drawing which does not address the elements of the article may indicate a lack of understanding, or incomplete reading.

detailed analysis is in the paper…

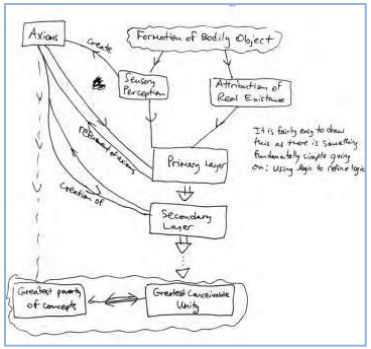
Summary: Types of drawings / students' learning styles

Abstract Representational	Student uses abstract symbols with a 1:1 correspondence between the symbol and the concept being represented.	intuitive, visual, deductive, reflective, sequential
Direct Symbolic	Student uses pictures of recognizable objects to represent concepts in the article in a 1: 1 mapping.	sensory, visual, inductive, active, sequential
Metaphorical / Analogical	Student represents concepts in the article through the use of metaphors or analogies.	sensory or intuitive, visual, deductive, reflective, global
Allegorical / Creative	Student represents the intention of the article with a pictorial story, or "what-if" scenario.	sensory, visual, inductive, reflective, global
Flow Chart	Student uses elements of temporal progression to indicate the development of concepts in the article.	sensory or intuitive, visual or verbal, inductive, reflective, sequential
Hybrid	Student's drawing shows qualities of two or more categories.	various combinations

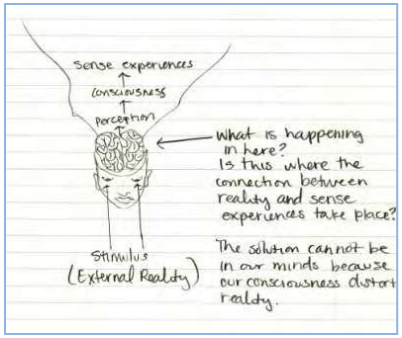
Incomplete understanding: Drawing shows either lack of understanding or incomplete reading

Which category most closely matches your style?

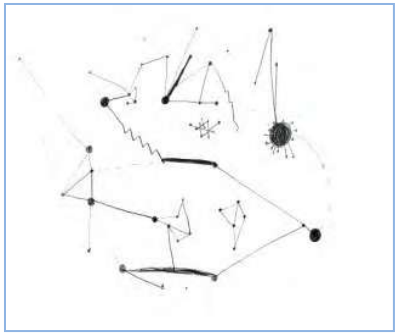
Flow Chart



Direct Symbolic



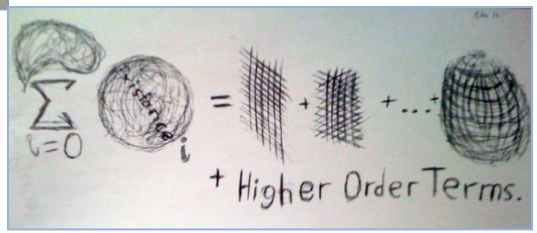
Abstract Representational

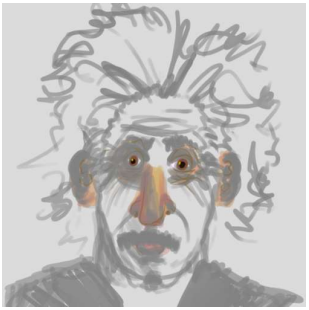


Metaphorical / Analogical

Allegorical / Creative

Hybrid





Incomplete Understanding

The importance of drawing for understanding

The NRC report Taking Science to School strongly recommends:

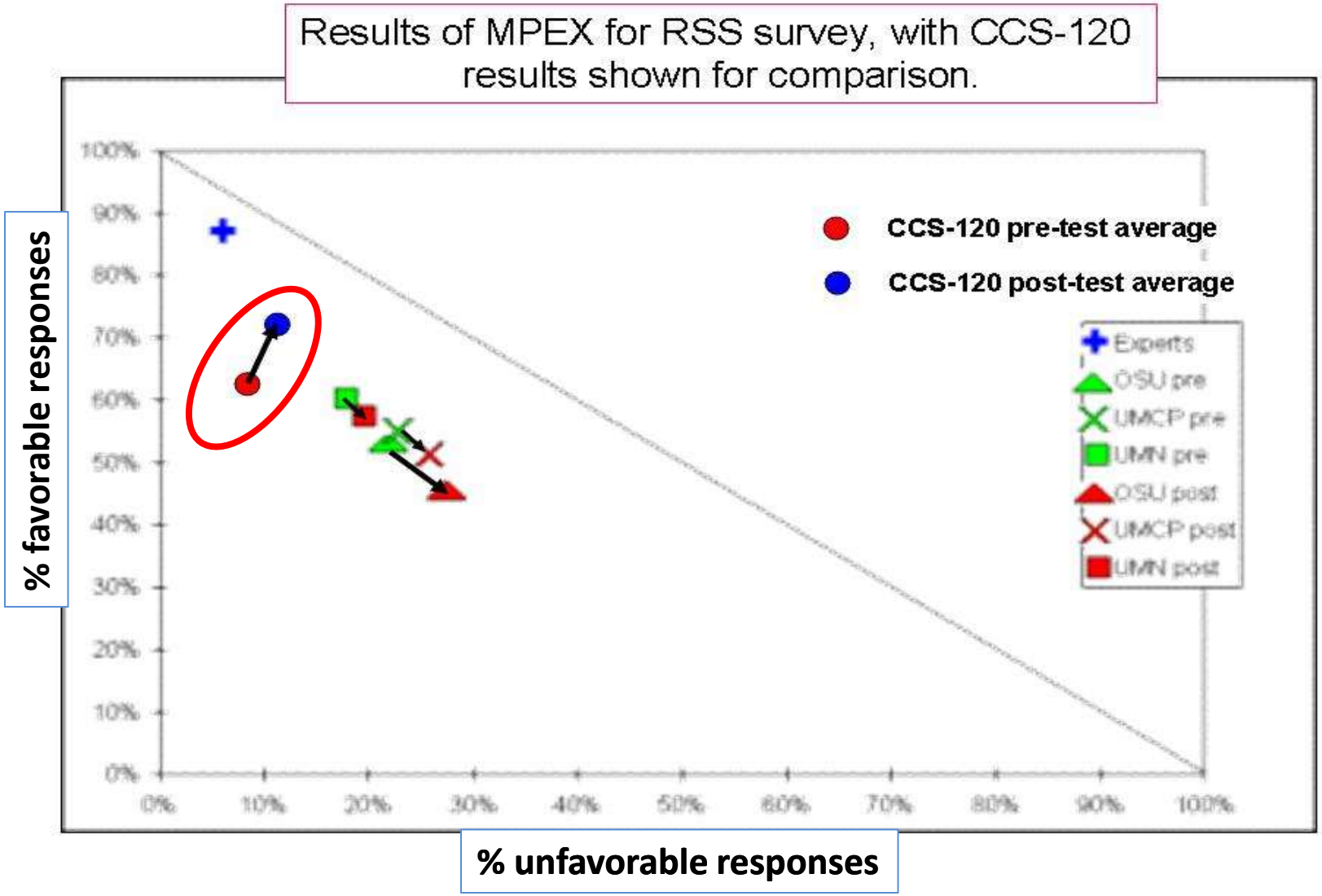
To support student sense-making in instruction, teachers need to know how students think, have strategies for eliciting their thinking as it develops, and use their own knowledge flexibly in order to interpret and respond strategically to student thinking (Duschl, et al., 2007, p. 312).

Students' drawings → students' learning preferences and ways of meaning-making

Hence, instructors can design appropriate learning strategies and content/contexts

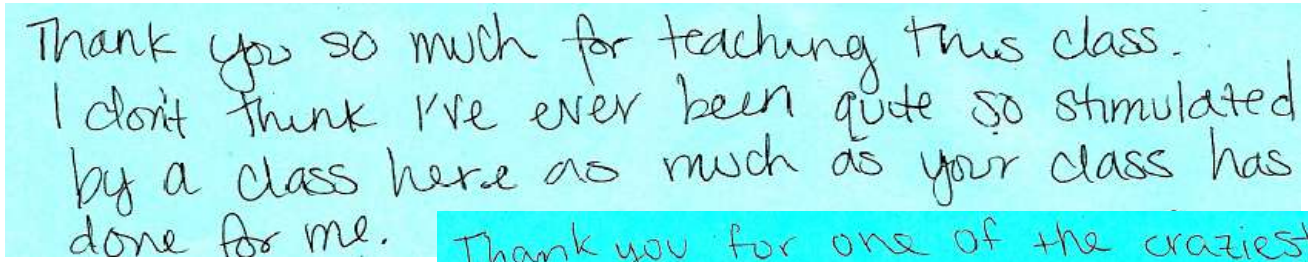
The instructor must constantly assess his/her own knowledge in order to be able to evaluate students' drawings !

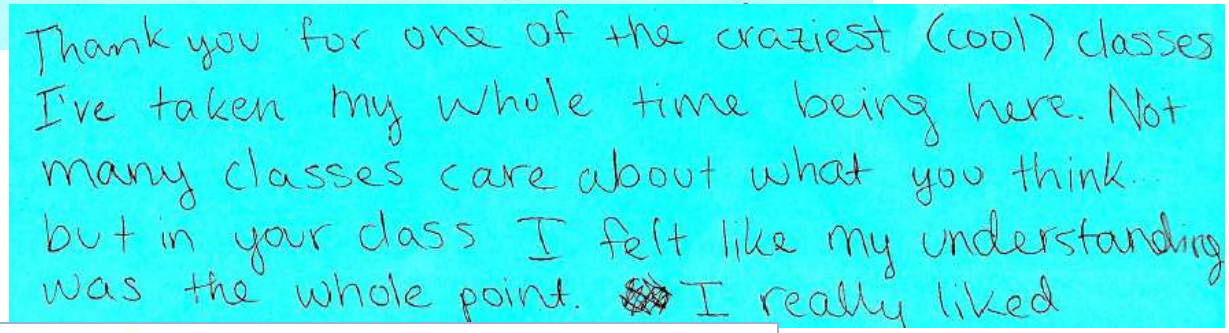
Attitudes towards physics improved in my students

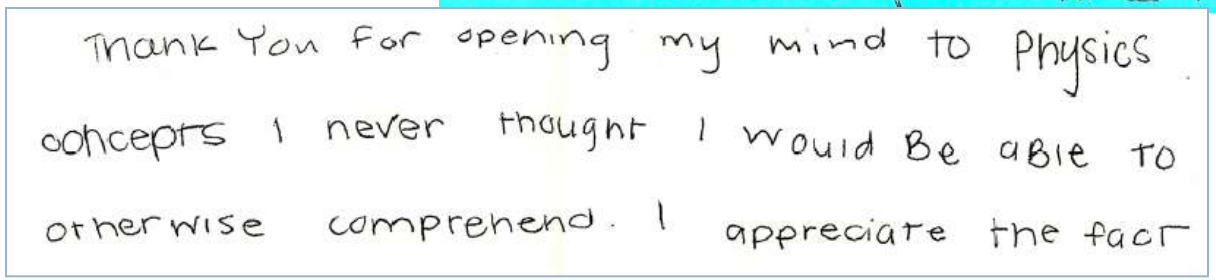


Attitudes toward physics improved during this course, in contrast with national surveys of students in traditional first-year physics courses.

Students really appreciate this approach







last exit card comments, 2012:

"This class has been so great! I'm really going to miss it."

"I'm really glad that I got to take this class, & that classes like this exist. I feel like I learned a lot & that I will retain it because I enjoyed learning it, and I think it is useful & really interesting information. It was awesome to learn about something so unlike what I normally study, and from so many different perspectives."

A sampler of my students' work

I showed this video during the actual lecture at the Arts in Learning Symposium, Nov. 3, 2012.

Not available for distribution on the web.

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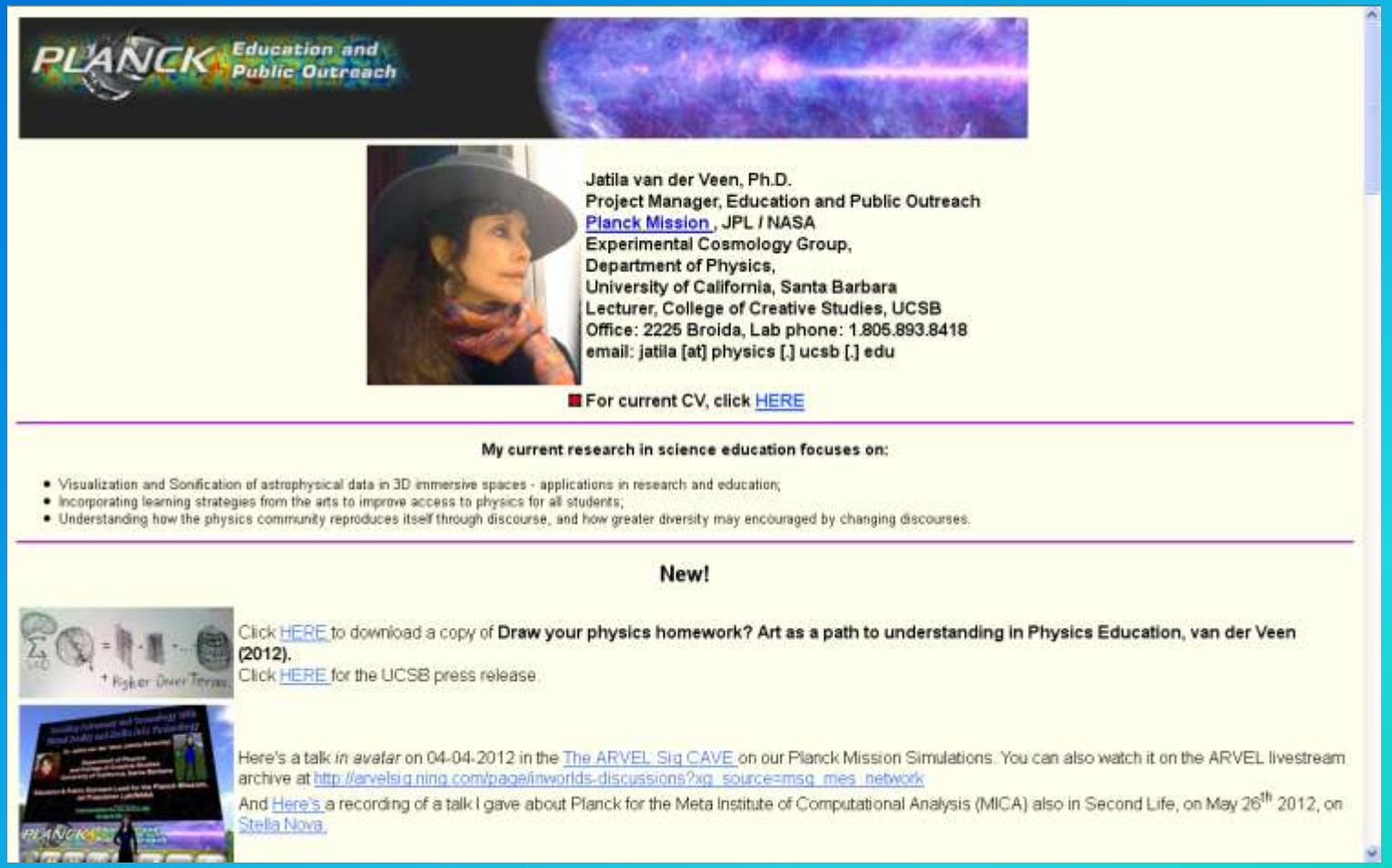
Choreography: Jonathan Madanikia, 2011
Musical compositions:
Fibonacci's Dream, Alex Rebro, 2007
From Your Perspective, Emily Robinowitz, 2010

Art work:
Students of CCS-120 , 2007 - 2012

Where you can get more information:

http://web.physics.ucsb.edu/~jatila



email: jatila@physics.ucsb.edu