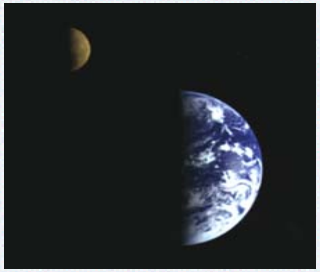
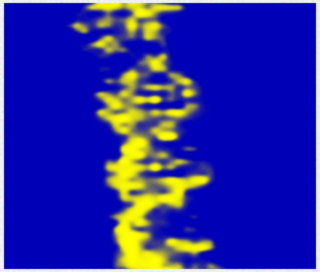
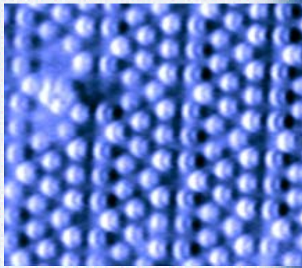
Using Construct-Centered Design to Align Curriculum, Instruction, and Assessment Development in Emerging Science

Jim Pellegrino, University of Illinois, Chicago

Namsoo Shin, University of Michigan

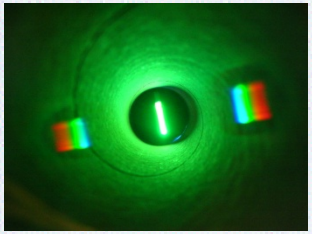
Overview of the Seminar

- Introduction to Construct-Centered Design
  - Rationale & Overview of its Components
- Examples of application within NCLT
  - Research: Learning progressions (UM)
  - Student materials: Curriculum materials and Learning technology (UM, UIUC, & UIC)
  - Teacher materials: Professional development (Purdue & UIC)
- Lessons Learned & Future Applications
- Questions and Discussion

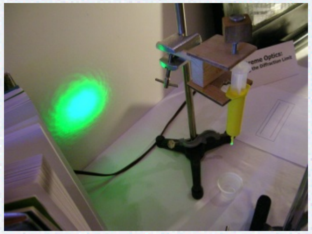
Center Mission & Vision

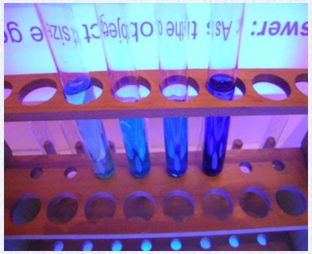
Mission: ***Build national capacity*** in Nanoscale Science & Engineering (NSE) Education (grades 7-16)

Vision: ***Develop a globally competitive*** NSE workforce and train a national cadre of leaders in NSE education



Learning and teaching through inquiry and design of nanoscale materials and systems for applications





Developing Curricula • **New Learning Standards** • **NSEE Knowledge Base**

Part 1

Construct-Centered Design as a Unifying Approach for Center Work on Curriculum, Instruction, & Assessment tied to the “Big Ideas”

What & Why of “Big ideas”

- What are big ideas?
  - the core concepts and principles of a field
- Why big ideas?
  - help learners understand a variety of ideas about a field provide ideas/models to explain a range of phenomena
  - allow learners to intellectually make individual, social, and political decisions regarding science and technology
  - provide insight into the development of the field or have a key influence on explaining the major ideas in the domain

The Big Ideas in NSE

Size & Scale

Structure of Matter

Quantum Effects

Forces & Interactions

Size-Dependent Properties

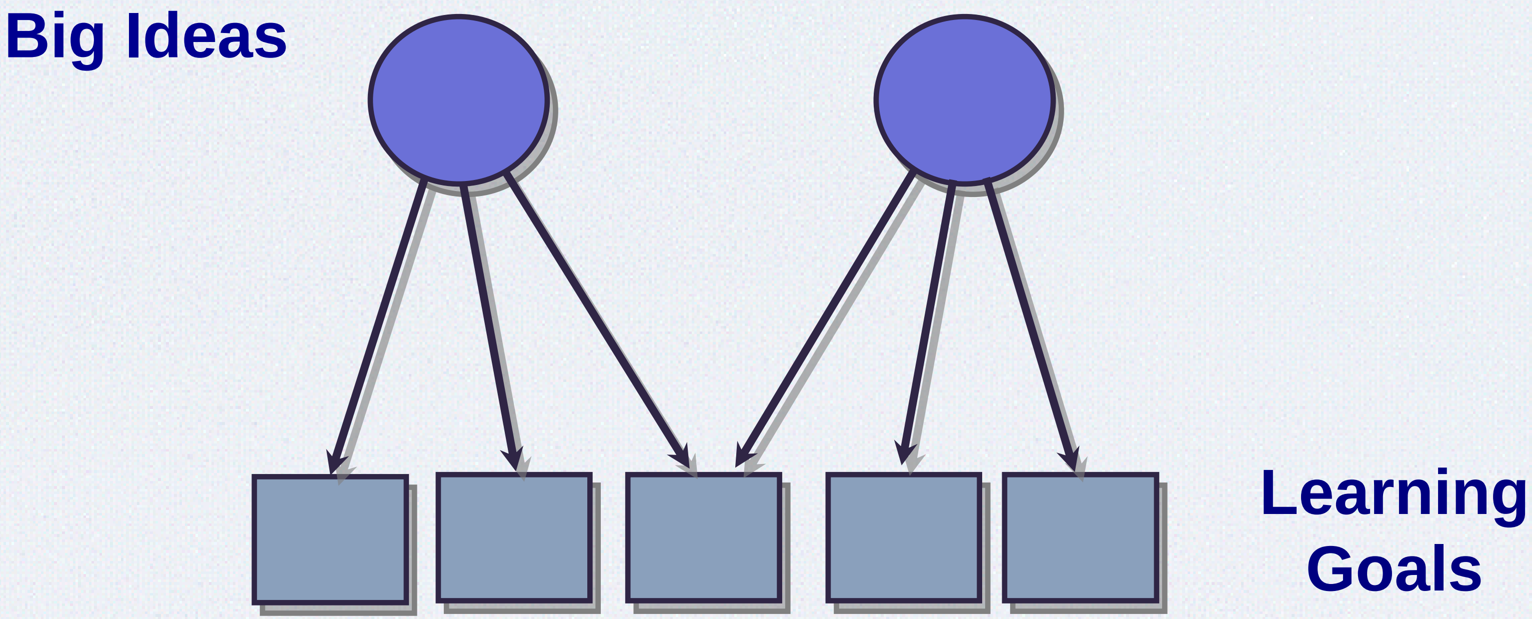
Self-Assembly

Tools & Instrumentation

Models & Simulations

Science, Technology & Society

How do we use the big ideas?



To help define construct domains & learning goals that can be used to align curriculum development, instruction, assessment, and teacher education

Construct-Centered Design (CCD)

- What is CCD?
    - Adaptation of aspects of learning-goals-driven design (Krajcik, McNeill, & Reiser, 2007) and evidence-centered design (Mislevy, et al., 2003; Pellegrino, et al., 2001)
        - Define knowledge domains (construct)
        - Use construct to align development of curriculum, instruction, and assessment
- Why use CCD?
    - Provides a systematic approach to developing instructional materials (for students and teachers), and assessment (formative & summative)
    - Facilitates the development of principled, coordinated research on teaching and learning

Stages of CCD Process

1. Define the Construct

- These might be derived from a set of “big ideas” in science or from standards or benchmarks
- Includes concepts that are not just related somehow to a big idea, but *necessary for building understanding* of the big idea
- Approach and “grain size” depend on the desired final product and intended use

2. Unpack Construct

define context

Grade level?

What subject?

How long is the intervention?

specify science content

alternative conceptions

prerequisite knowledge

relevant phenomena

potential student difficulties

links to standards

3. Develop Claims

- A claim is about what the student "knows" and "understands" and how they do so
- Incorporates both content and cognitive skills
- Uses descriptive and specific verbs to clarify learning performances. For example:
  - describe, analyze, compare and contrast, design
  - explain content using evidence and reasoning
  - build and describe models

Level I Performances: Simple behavioral/cognitive objectives	**Level II Performances:** Behaviors requiring application of more complex mental operations	**Level III Performances:** Behaviors requiring application of more complex mental operations
After . . . the student will be able to. . . find gather data describe do make compute Measure use illustrate examine manipulate apparatus recognize identify classify recognize and cite evidence for	**After . . . the student will be able to. . .** prove organize data apply construct distinguish between (or among) state a problem contrast compare interpret identify the variables differentiate relate discriminate reformulate justify estimate specify the limitations and assumptions analyze	**After . . . the student will be able to. . .** synthesize infer generalize from data predict deduce discuss critically integrate discover formulate hypotheses reorganize manipulate ideas propose reasons and defend them

4. Define Evidence

- What will you accept as ***evidence*** in support of a ***claim*** that a learner has the desired knowledge?
- Specific learner performances and/or work products that you would accept as indicative that a ***claim*** has been satisfied.
- The ***features*** of the work products and performances that you expect to see and their value and importance in supporting a ***claim***

5. Design Situations or Tasks

- What particular tasks, questions or situations will
  - help students develop knowledge
  - bring about a response

  that will provide sufficient evidence to support the student learning claim

- A single task or situation may provide evidence for more than one claim.

- Multiple tasks and performances may be necessary to provide evidence in support of a single claim.

6. Review Products

- Based on the internal and external reviews and pilot studies, iterate through relevant portions of the design process.

- Confirm that the products meet all CCD criteria
  - who they are intended for
  - how they are intended to be used

A Possible Metaphor for What the NCLT is Trying to Do Using Construct-Centered Design


Self-Assembly
Is it a “big idea”?
What concepts are affecting it?
What claims can be formulated using this approach?
Which concepts to unpack?
What evidence can support the claims?
At what level should they be unpacked?
What tasks can demonstrate the evidence?
Can self-assembly be used as a vehicle for learning about these concepts?
How to develop instruction that aligns with the claim-evidence-task?
What prior knowledge to consider?
Where and how should design activities be incorporated?
Can one instruction respond to more than one claim?
What instructional method/sequence is optimal?

Part 2

Areas Where CCD is Being Applied

CCD Examples

- Research
  - Learning Progressions (UM)
- Student Materials
  - Summer Science Camp (UM & UIUC)
    - Curriculum with learning technology
  - Learning Technology (UIC)
- Teacher Materials
  - Professional Development (Purdue & UIC)

These applications encompass development of curriculum materials, learning technology, teacher education, and assessment, in addition to research efforts.

Research

- Research on Learning Progressions: UM
- Purpose

  To empirically derive a learning progression that describes the development of grade 7-14 students' models of the structure and interactions of atoms as they relate to nanoscale science and engineering (NSE)
- Big ideas

  Structure of Matter, Forces & Interactions (and ultimately also Size-Dependent Properties and Quantum Effects)

Research

Content

Kinetic theory: Particles/atoms are always in motion (except at 0° K)

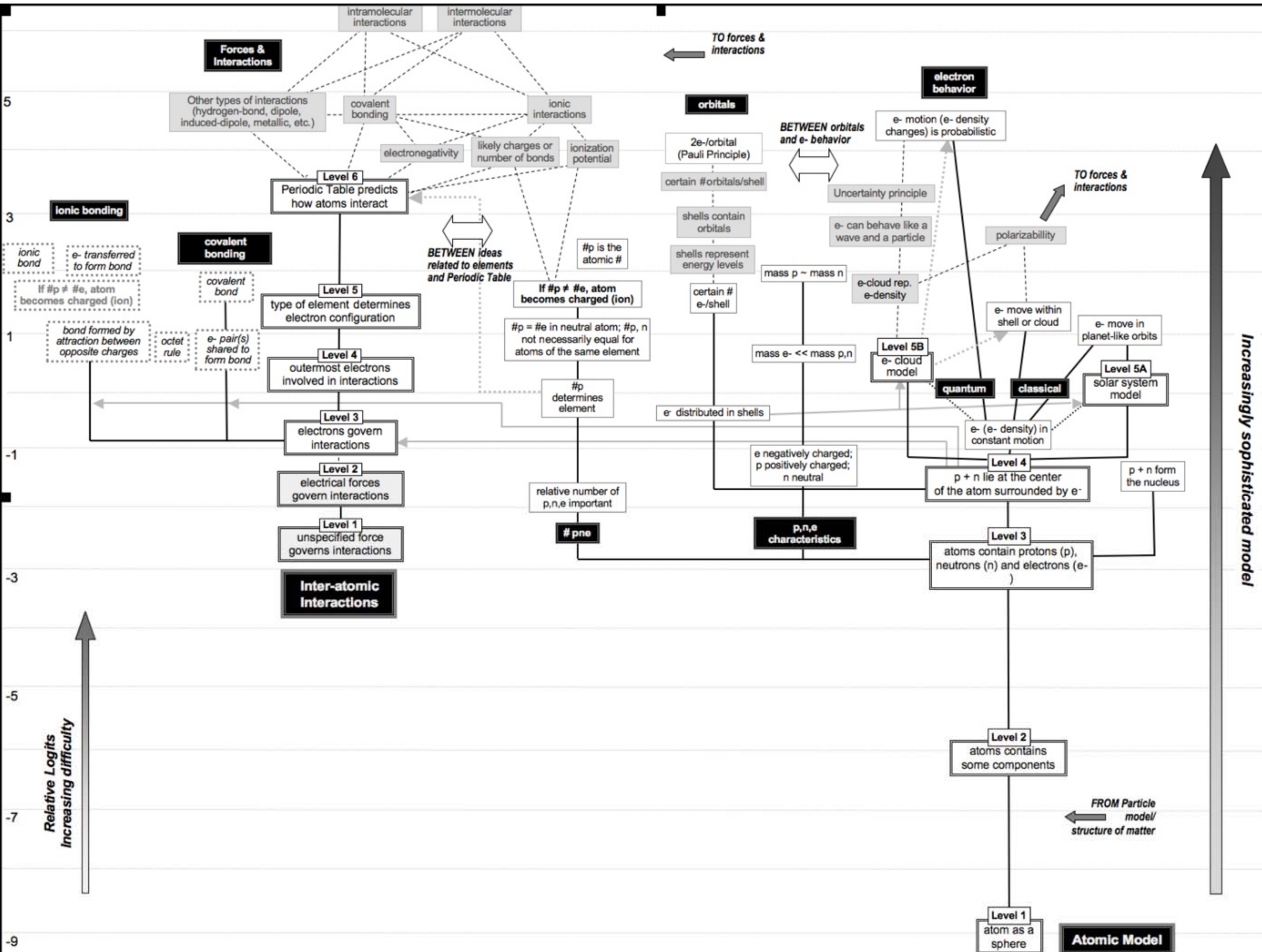
Claim	Evidence
The student is able to:	***The student work should include:***
incorporate particle motion into their descriptions of the structure of matter	1. a description of the behavior of the particles that make up matter 2. a model of matter that includes: - all matter is made up of particles/(atoms) - the particles are too small to see with the naked eye. - the particles that make up matter are in constant motion - the inherent motion is often called thermal energy

Research: Developing Instrument

Content

Kinetic theory: Particles/atoms are always in motion (except at 0° K)

Task
Interview Protocol
If we have a special instrument that allows us to zoom in and see what this metal is made of, what would we see? Draw what you think it will look like and explain your model.



intramolecular interactions
intermolecular interactions
Forces & Interactions
TO forces & interactions
electron behavior
orbitals
Other types of interactions (hydrogen-bond, dipole, induced-dipole, metallic, etc.)
covalent bonding
ionic interactions
electronegativity
likely charges or number of bonds
ionization potential
2e-/orbital (Pauli Principle)
BETWEEN orbitals and e- behavior
e- motion (e- density changes) is probabilistic
Level 6
Periodic Table predicts how atoms interact
certain #orbitals/shell
Uncertainty principle
TO forces & interactions
ionic bonding
shells contain orbitals
e- can behave like a wave and a particle
covalent bonding
polarizabillity
ionic bond
e- transferred to form bond
BETWEEN ideas related to elements and Periodic Table
#p is the atomic #
shells represent energy levels
If #p ≠ #e, atom becomes charged (ion)
covalent bond
mass p ~ mass n
e-cloud rep. e-density
Level 5
type of element determines electron configuration
If #p ≠ #e, atom becomes charged (ion)
certain # e-/shell
e- move within shell or cloud
bond formed by attraction between opposite charges
octet rule
e- pair(s) shared to form bond
#p = #e in neutral atom; #p, n not necessarily equal for atoms of the same element
e- move in planet-like orbits
Level 4
outermost electrons involved in interactions
mass e- << mass p,n
Level 5B
e- cloud model
Level 5A
solar system model
quantum
classical
#p determines element
e- distributed in shells
Level 3
electrons govern interactions
e- (e- density) in constant motion
e negatively charged; p positively charged; n neutral
Level 4
p + n lie at the center of the atom surrounded by e-
p + n form the nucleus
Level 2
electrical forces govern interactions
relative number of p,n,e important
Level 1
unspecified force governs interactions
pne
p,n,e characteristics
Level 3
atoms contain protons (p), neutrons (n) and electrons (e-)
Inter-atomic Interactions
Increasingly sophisticated model
Relative Logits
Increasing difficulty
Level 2
atoms contains some components
FROM Particle model/ structure of matter
Level 1
atom as a sphere
Atomic Model
5
3
1
-1
-3
-5
-7
-9

Figure 3

Research: Developing Instrument

Assessment type

interview, multiple-choice item, open-ended item, work product, or performance

Presentation Type

- How tasks are presented
- How tasks are scheduled to be administered

Scoring Process

How evidence is identified, scored, and accumulated

Student Materials

- Curriculum development for Informal Education (UM & UIUC)

- Purpose

  To develop 2-week curriculum unit for middle school students

- Big Idea

  Size and Scale

Student Materials

Big Idea: Size and Scale

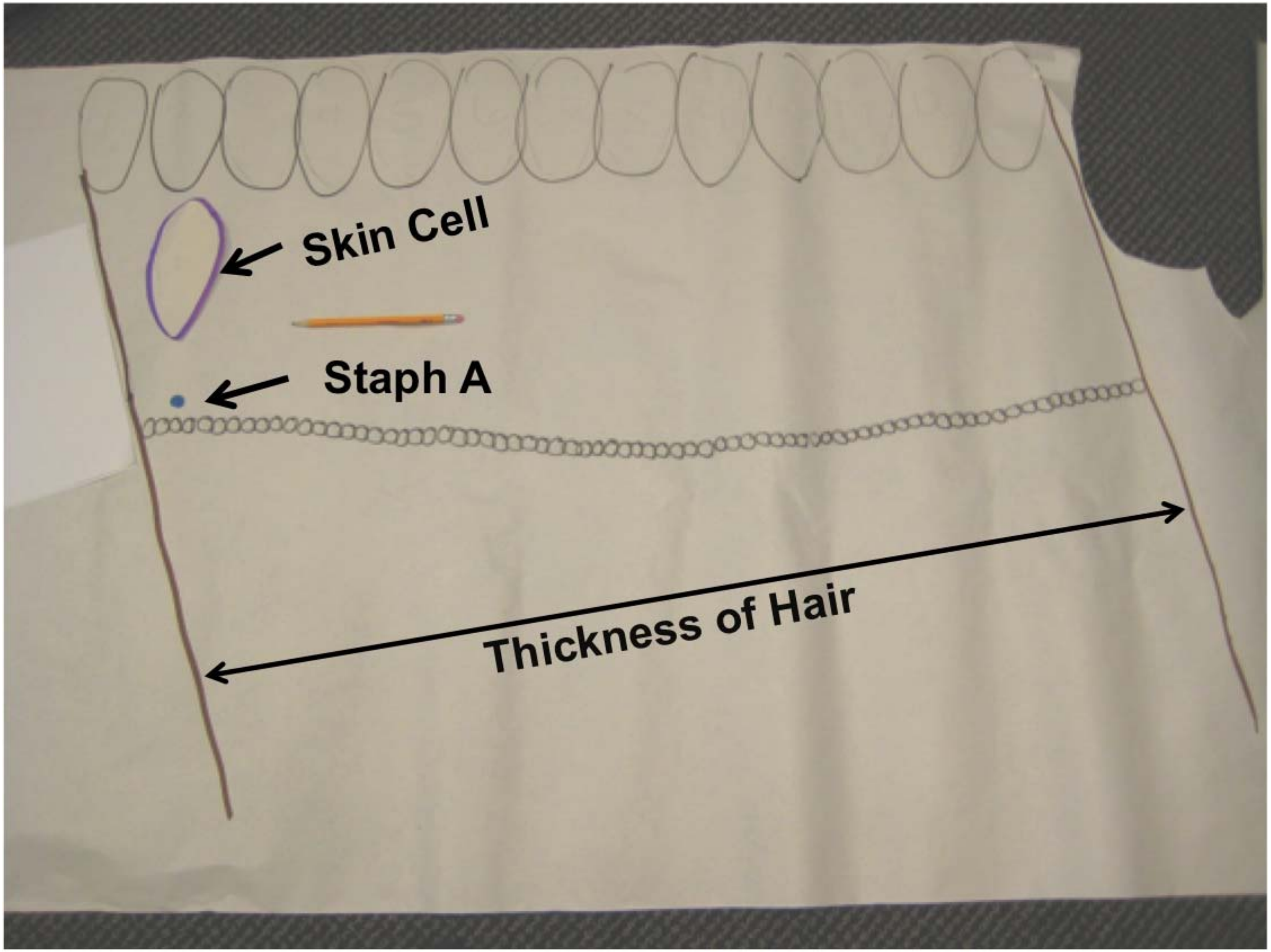
Claim	Evidence
The student is able to:	***The student work should include:***
estimate the sizes of a range of scientifically important objects in terms of a convenient and familiar reference object	an estimate of how many times smaller they are relative to a small, macroscopic reference object, within a factor of two.

Student Materials

Big Idea: Size and Scale

Task (Learning)
Hand-on instructional activities
Measure the thickness of a hair by seeing how many line up across a millimeter. Using the microscope, compare the thickness of a hair on a slide to your own cheek cells and to a prepared slide of skin cells. Using the tracing of the sizes of hair, skin cell, and Staphylococcus Aureus at 2000X magnification obtained through the projecting microscope, calculate the size in micrometers of these three objects.

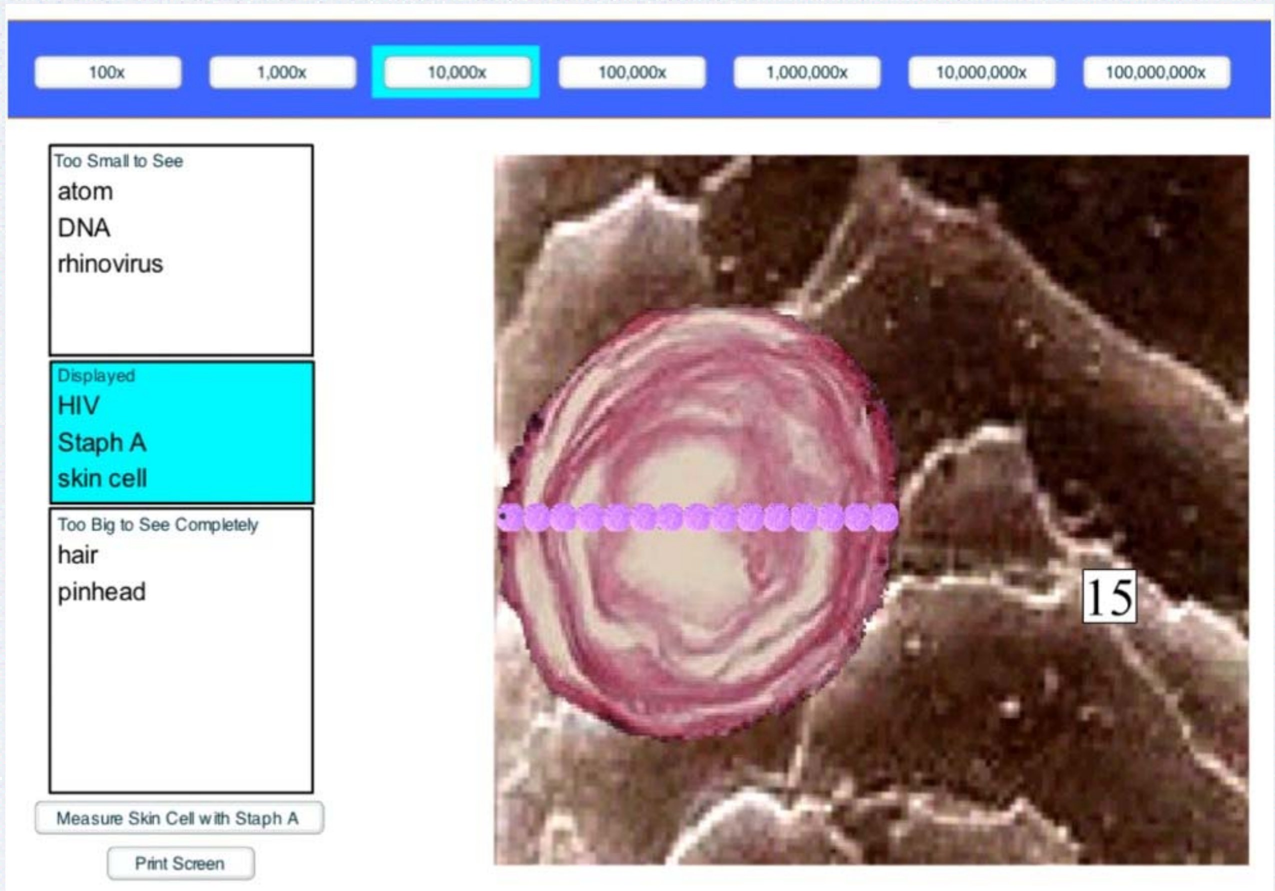
Student's Artifacts



Student Materials

Big Idea: Size and Scale

Task (Learning)
Computer simulation
Using the images of hair, skin cell, staph A, HIV, rhinovirus, DNA, and atom, calculate the relative and absolute size of these objects.



Student Materials

Big Idea: Size and Scale

Task (Assessment)
Relative Size
How many times smaller is the Staph A compared to the skin cell? How many times smaller is the skin cell compared to the width of a hair? How many times smaller is the Staph A compared to the width of a hair? How did you figure this out?

Student Materials

- Learning Technology: UIC
- Purpose

  To develop curriculum materials for middle school students to teach Interactions of energy with matter
- Big ideas

  Forces & Interactions, and Self-Assembly

Student Materials

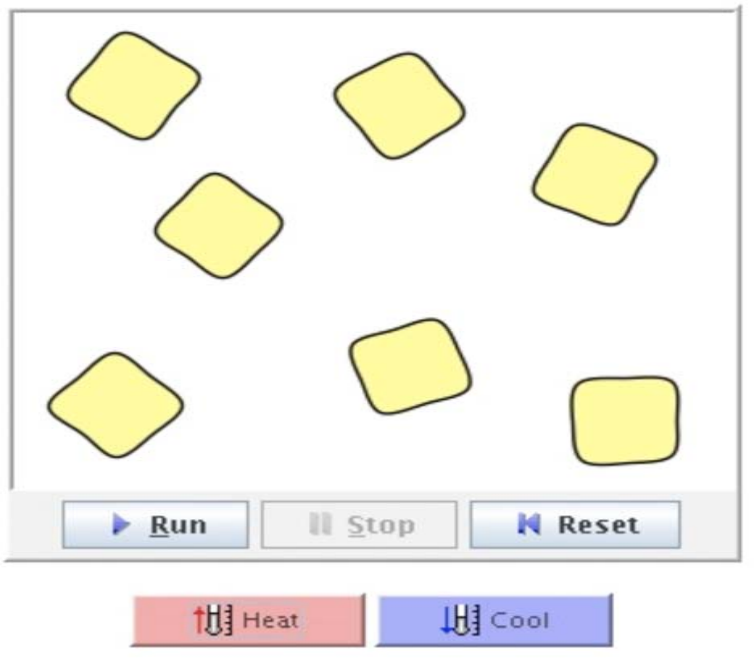
Big idea: Forces & Interactions, and Self-Assembly

Claim	Evidence
The student is able to:	***The student work should include:***
predict how changes of energy affect the movement of atoms as materials change structure.	*(Shown a comparison of the same material at different temperatures), a written description of* - every substance has heat, regardless of its temperature. - that the system has less heat/energy at lower temperatures, while at higher temperatures it has more

Student Materials

Big idea: Forces & Interactions, and Self-Assembly

Task (Learning)
Computer simulation
[*Given a simulation of four atoms exhibiting random motion in a system whose energy can be manipulated by a heat gauge*] Describe the movement of these atoms and what happens when the temperature of the system is increased or decreased. Why does this occur when the temperature is changed?



Molecular Workbench simulation.

Contextualization

- connect content to real world, and define relevant phenomena and driving (focus) question

↕

Learning Tasks

- incorporate: activities, relevant phenomena, and simulations/animations
- scaffold student learning using text, discussion, and activities

↕

Instructional Sequence

- create a logical progression
- define sub-learning goals *(may require mini-unpacking step*)

↕

Assessment Strategies

- formative: potential discussion questions
- summative: posttest (written, oral, project, etc.)

↕

Assessment Tasks

- Assessment type, Presentation type, and Scoring Strategies.

Teacher Materials

- Professional Development: Purdue and UIC

- Purpose

    To develop educative curriculum materials for high school teachers

Big Idea

    Self-Assembly

Teacher Materials

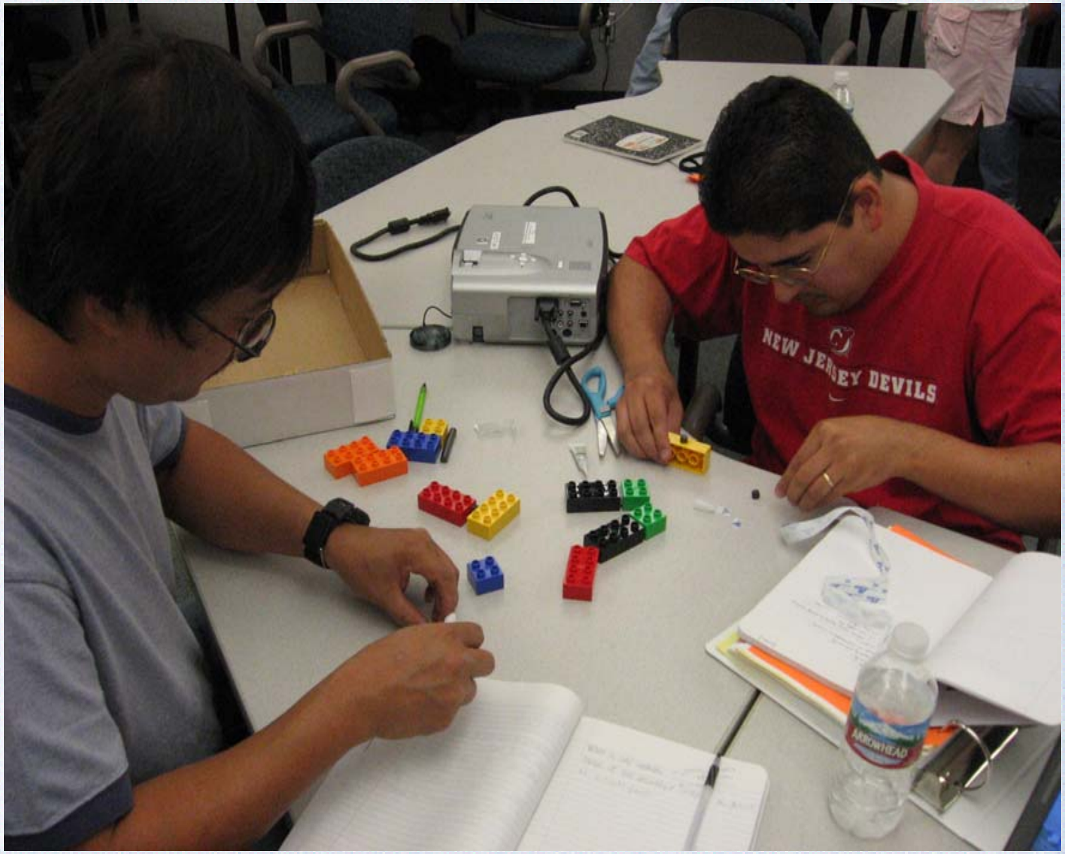
Big idea: Self-Assembly

Claim	Evidence
The student will:	***The student work should include:***
have an awareness of the nature of design, specifically design of components and systems at the nanoscale.	A written discussion of comments on using discoveries in nature as a basis for design, considering multiple components at the same time, and iterative nature of design process.

Teacher Materials

Big idea: Self-Assembly

Task (Learning)
Hand-on instructional activities
Students design a model of a self-assembling system using legos and blocks with magnets and Velcro. Following the activity, there is a discussion on what it means to design with emphasis on the following ideas: iteration, systems, and using nature as a basis for design



Background Knowledge

science content the teacher needs to know to be prepared to teach and deal with students' ideas and preconceptions

Teaching Strategies

- suggestions for lesson setup and student motivators
- eliciting students' ideas, questions, and interests

Students' Ideas

- prior knowledge, prior life and academic experiences
- potential student difficulties, alternative ideas, and students' interests

Supporting Inquiry

teacher- vs. student-directed inquiry

Adaptation

- rationales for instructional material design decisions
- multiple phenomena, first-hand experiences, and hints for contextualizing

Assessment Strategies and Tasks

Part 3

Lessons Learned & Future Applications within NCLT

Uses & Benefits

- Helps to organize the content within the big idea
- Helps ascertain how well an activity or performance characterizes student understanding of *all* of the content within the big idea
- Provides a clear chain of reasoning from big idea to curriculum, instruction & assessment to help ensure coherence and construct validity, as well as alignment.

Suggestions

- Unpack systematically
  - First, specifying all of the content in the big idea (or learning goal)
  - Second, unpacking the rest of the components in a more organized way

- Provide concrete examples to clarify the process

Limitations

- The initial part of the process (define a construct and unpack a construct) can be very specific and too narrow -- need to consider a “useful grain size” and avoid infinite regress
- It’s a process, not a cookbook recipe, so it is still difficult to create assessment and curriculum materials.
- There are challenges in identifying the differences among claims, evidence, and tasks

Ways We are Supporting the Process

Go to http://assessment-ws.wikispaces.com

Assessment Workshop, Aug'07

NCLT National Center for Learning and Teaching in Nanoscale Science and Engineering

NCLT has developed a Center-wide systematic approach to developing assessments. This approach includes mapping out the knowledge domains associated with nanoscale science and technology and developing assessments of that knowledge for various purposes, including supporting instructional design and understanding how students' ideas of nanoscale science develop over time. Designing good assessments for evaluating student understanding is critical for all aspects of work in the NCLT. To unify our assessment approaches in a consistent, principled way, we propose using a method that aligns with ideas discussed in the contemporary literature on designing and constructing valid assessment items. This document is designed to provide directives and definitions for application of an NCLT version of an "Evidence-Centered Assessment Design" process. The process includes unpacking a big idea, making claims about what students should know, defining evidence that supports such claims, and developing tasks that will provide the proper evidence. Below is a summary of the guidelines. You can download the guidelines, which also contains examples below.

NCLT_Assess_Guidelines.pdf

Assessment Design Process

Step 1. *Select the big idea you wish to assess*

• Use big Idea document (http://www.hice.org/projects/nano/index.html) to select the ideas to examine.

Step 2. *Identify the grade level of the students*

• What grade range of learner are you concerned with? Students at different grade ranges have different knowledge and experiences that influence their learning and that are appropriate targets for instruction and assessment.

Step 3. *Unpack the big idea (this is possibly the most time-consuming and difficult process.)*

• **Unpacking** – Unpacking involves taking the big idea (construct), breaking it apart and expanding the various concepts to identify and explicitly describe the critical components important for understanding the big idea (See example 1)

1. Identify and clarify critical concepts

• *Identify and clarify the important concepts/ideas that you are trying to help students learn and assess. Explain what each of these ideas mean. At what level and depth of understanding do you expect learners to understand the idea/concept? Creating a concept map can help identify the ideas students will need to know and identify the links among ideas.*

2. Identify prior knowledge

• *Identify and describe what prior knowledge students will need to understand before learning these concepts*

Part 4
Questions & Discussion

Frequently Asked Questions

- Where to stop the unpacking process and call it prerequisite knowledge and do so in a principled way?
- What cognitive skill/process skill to use in each claim, in a principled way?
- What are the differences between claims, evidence, and tasks?