The Nature of Matter-
Developing a learning progression

THE LEARNING TRAJECTORY & NANO-SLAM WORK CIRCLES

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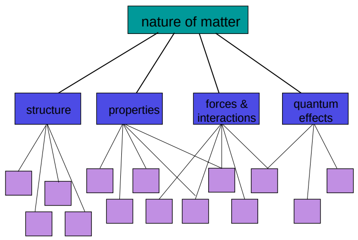
INTRODUCTION

A strong foundation of nanoscience literacy must include a robust model of not only the structure of matter, but also of properties and what determines those properties, as well as how matter behaves and interacts under a variety of conditions. Developing an empirical learning progression will provide insight into the appropriate points to introduce nanoscience concepts into the curriculum.

EVIDENCE-CENTERED DESIGN[1]

Claim space-
We unpacked the concepts behind the nature of matter as it pertains to nanoscience to specify what we wanted to assess.



Parts of four of the big ideas of nanoscience (blue) were unpacked into key scientific concepts or models (e.g. kinetic theory, atomic model, etc (purple boxes)). These concepts are on the level of standards or benchmarks. Each of these was further unpacked in order to define exactly what students should know.

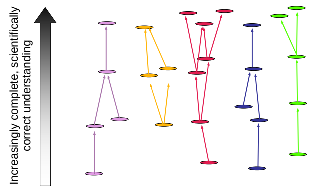
Evidence and Task Models-
Each idea within the claim space was evaluated to determine what type of task or question would provide proof of the desired knowledge. Tasks and questions were then developed to elicit the desired evidence.

RESEARCH AIMS

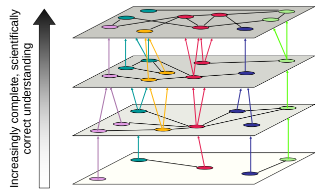
Development and validation of a learning progression based on actual students' knowledge and understanding.

Characterization of students' ability to make connections between ideas and utilization of that knowledge to develop assessments that evaluate conceptual understanding.

A MODEL OF CONCEPTUAL UNDERSTANDING



Traditional instruction and asssessment focus on targeted, isolated topics, which leads to compartmentalized knowledge



We define learning progressions as strategic sequencing that promotes both branching out and forming connections between ideas related to a core scientific concept.

Figure Legend- Each color dot represents one of the different areas being assessed. The matching color lines are the linear progressions that represent how these topics are typically taught and assessed. The black lines on the planes represent the connections between the areas. Being able to make these connections constitutes conceptual understanding

METHODS

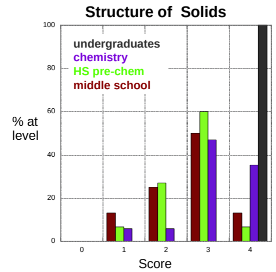
Instrument-
Semi-structured interviews were performed with individual students to assess their conceptual understanding of the nature of matter.

Population-
Public, middle and high school students from
- a diverse, urban community, ~50% low SES
- suburban and rural, predominantly white middle-class communities

Data Analysis-
A coding scheme was developed to describe level of student understanding.
- each concept was assigned levels ranging from "does not know" to "expert understanding"
- yes/no evaluation of unpacked individual ideas

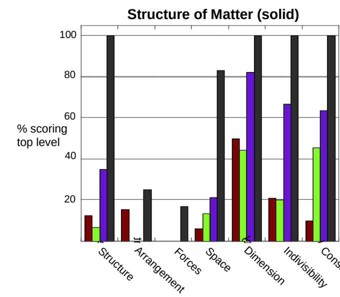
PRELIMINARY RESULTS

Tracking student learning



Coding scheme
0 does not know
1 continuous model
2 particles, but incorrect, or inconsistent
3 particle model, but incomplete
4 solid consists of ordered particles that are arranged in a compact way

While there is not a statistically significant difference in the levels between the middle school and pre-chemistry high school students, there is a general improvement in students' models of the structure of solids. This pattern is typical for most of the other concepts assessed.



undergraduates
chemistry
HS pre-chem
middle school

Graph key
- structure of solids
- importance of atom arrangements
- inter-particle forces
- space between atoms.
- dimensionality of atoms
- characteristics of atoms on the edge.
- consistency of size and shape of atoms

Growth in knowledge was observed for most aspects of the structure of matter as students moved through the science curriculum.

Students do not appear to gain understanding about inter-particle forces or the importance of the arrangement of atoms from the curriculum.

Building a tentative multi-dimensional learning progression

Particle model of matter (solid)		
	Individual Idea	% total students
P1	Solids are made up of particles	83%
P2	Particles are arranged in a compact way	50%
P3	Particles are arranged in an ordered way	44%
P4	The particles are atoms	42%
P5	The particles/atoms are in constant motion	12%
P6	The arrangement of atoms determines the properties	7%
P7	The arrangement of atoms determines the substance	6%

Progressions were developed for each of the major concepts under the big ideas (purple boxes) by ordering the percentage of students that understood the individual ideas associated with them.

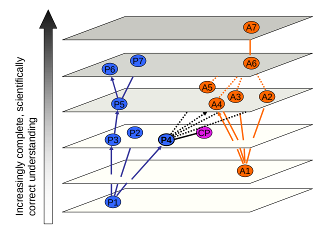
For the particle model of matter,
- if student understands P7, then he understands P1-P6
- progression fits 31 of 35 students

Atomic Model		
	Individual Idea	% total students
A1	All matter is made up of atoms	72%
A2	Atoms are made of protons, electrons and neutrons	39%
A3	Protons and neutrons make up the nucleus which is surrounded by electrons	39%
A4	Protons and neutrons are approximately of the same mass, which is much greater than the mass of electrons	31%
A5	Electron cloud model	28%
A6	The relative number of protons, electrons and neutrons is important	23%
A7	Probability model for electron behavior; Heisenberg Uncertainty Principle	9%

Similarly, a progression was developed for atomic structure.
- fits 29 of 33 students

CP Characteristics of particles-		
Individual Idea	% students *particle model*	% students *particles are atoms*
Dimension of particles (2D or 3D)	45%	100%
Particles on the surface vs. bulk particles	25%	86%
Consistency of size	33%	83%
Consistency of shape	29%	80%

Once they make the particle-atom connection, students seem to better understand the characteristics of the particles.



- particle model of matter
- atomic model
- characteristics of properties
- connection between ideas
- tentative connection

The individual progressions were merged to form a multi-dimensional progression.

We will continue building individual progressions and work to connect them

REFERENCES

1. Mislevy, R. J., & Riconscente, M. (2005). *Evidence-centered assessment design: Layers, structures, and terminology (PADI Technical Report 9).* Menlo Park, CA: SRI International

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