The Concord Consortium

Linking Student Achievement, Teacher Professional Development, and the Use of Inquiry-based Computer Models in Science

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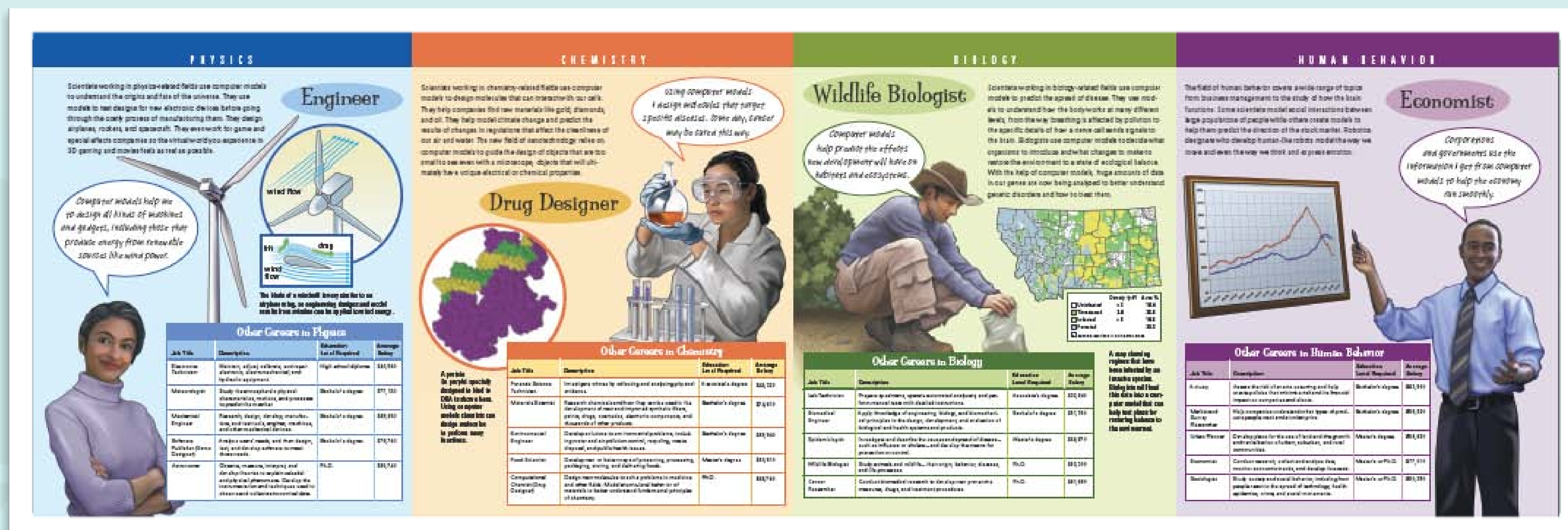
Realizing the Promise of Education Technology

- A nonprofit educational research and development organization based in Concord, Massachusetts.
- We create interactive inquiry-oriented materials that leverage the power of information technologies.
- Our goal is to improve learning opportunities for ALL students.

RI-ITEST Goals

- Improve science content knowledge.
- Increase student awareness of related computer modeling careers.
- Bring together a more connected understanding of how the world of atoms and molecules links physics, chemistry, and biology.



Static attempt at teaching phase change

The phases of matter

Solid, liquid, and gas

Most of the matter you find around you is in one of three phases: solid, liquid, or gas. A **solid** holds its shape and does not flow. The molecules in a solid vibrate in place, but on average, don't move far from their places. A **liquid** holds its *volume*, but does not hold its shape — it flows. The molecules in a liquid are about as close together as they are in a solid, but have enough energy to exchange positions with their neighbors. Liquids flow because the molecules can move around. A **gas** flows like a liquid, but can also expand or contract to fill a container. A gas does not hold its volume. The molecules in a gas have enough energy to completely break away from each other and are much farther apart than molecules in a liquid or solid.

Intermolecular forces

When they are close together, molecules are attracted through *intermolecular forces*. These **intermolecular forces** have different strengths for different molecules. The strength of the intermolecular forces determines whether matter exists as a solid, liquid, or gas at any given temperature.

Temperature vs. intermolecular forces

Within all matter there is a constant competition between temperature and intermolecular forces. The kinetic energy from temperature tends to push molecules apart. When temperature wins the competition, molecules fly apart and you have a gas. The intermolecular forces tend to bring molecules together. When intermolecular forces win the competition, molecules clump tightly together and you have a solid. Liquid is somewhere in the middle. Molecules in a liquid are not stuck firmly together, but they cannot escape and fly away either.

Strength of intermolecular forces

Iron is a solid at room temperature. Water is a liquid at room temperature. This tells you that the intermolecular forces between iron atoms are stronger than those between water molecules. In fact, iron is used for building things because it so strong. The strength of solid iron is another effect of the strong intermolecular forces between iron atoms.

Temperature

As the temperature changes, the balance between temperature and intermolecular forces changes. At temperatures below 0°C, the intermolecular forces in water are strong enough to overcome temperature and water becomes solid (ice).

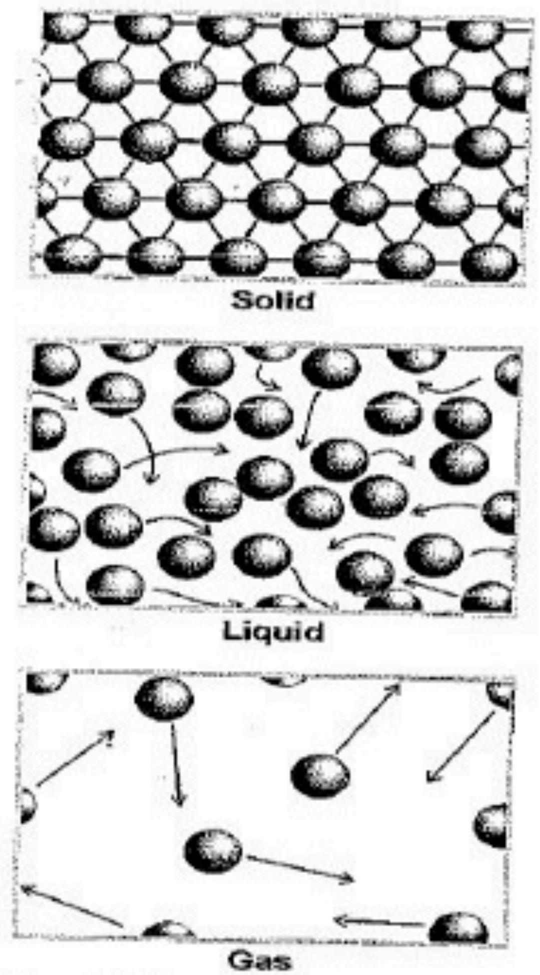


Figure 7.11: *Molecules (or atoms) in the solid, liquid, and gas phases.*

Ideal Learning Environment

- Dynamic nature of atomic/molecular systems not easily conveyed with text and static images.

- Animations help, but don’t allow students to construct knowledge. Student is passive learner.

- **Models which are computed in real-time allow users to probe the simulation by changing parameters. Student becomes an active learner.**

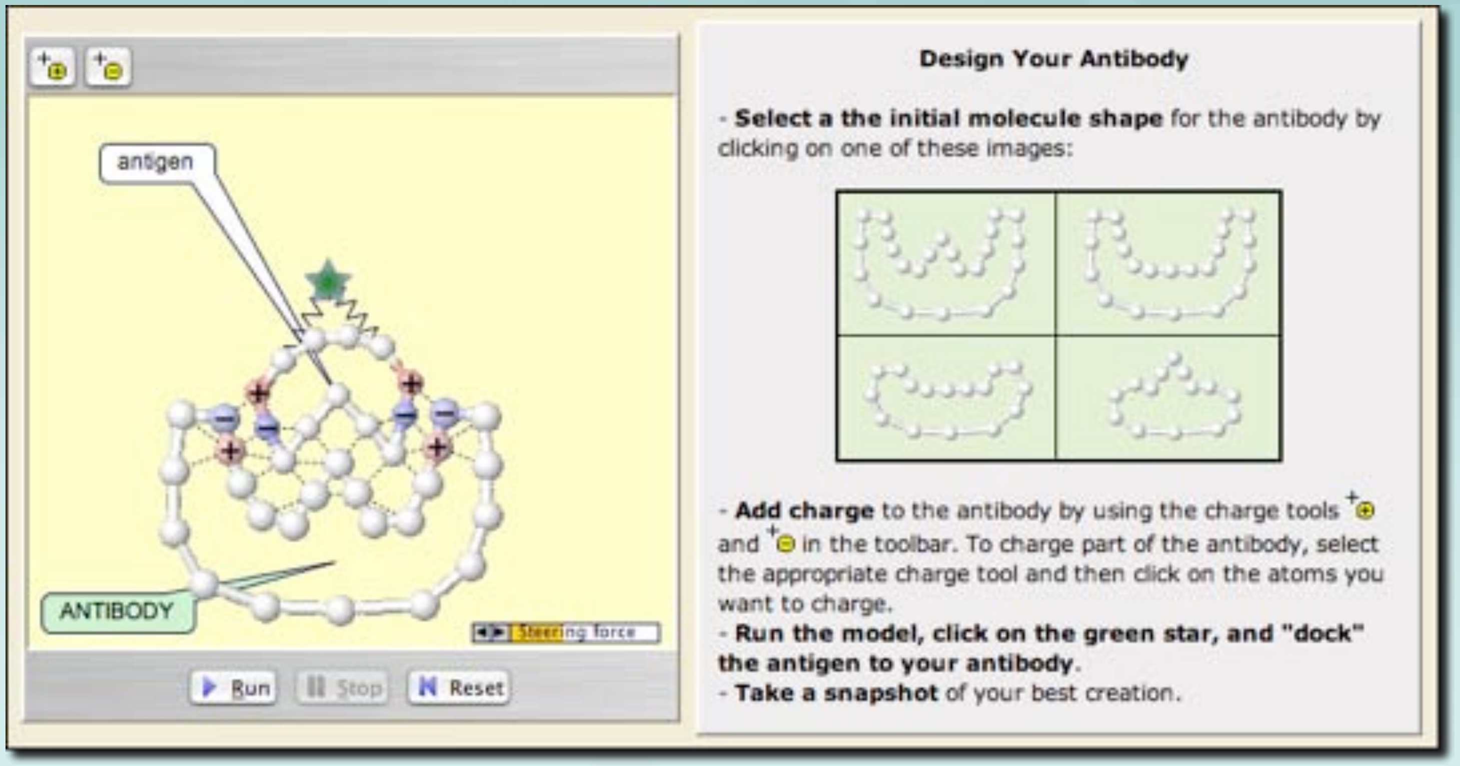
The Modeling Environment

The Molecular Workbench – a molecular dynamics tool.

- Open-source cross-platform molecular dynamic engine.
- Calculates complex real-time interactions between atoms and molecules.
- User friendly interface for creating custom model-based activities.

Various Model Types

- 2D and 3D Molecular Dynamics Models
- 3D Exploration of Static Molecular Representation
- Flash based models
- Abstract dynamic models of DNA, RNA and proteins



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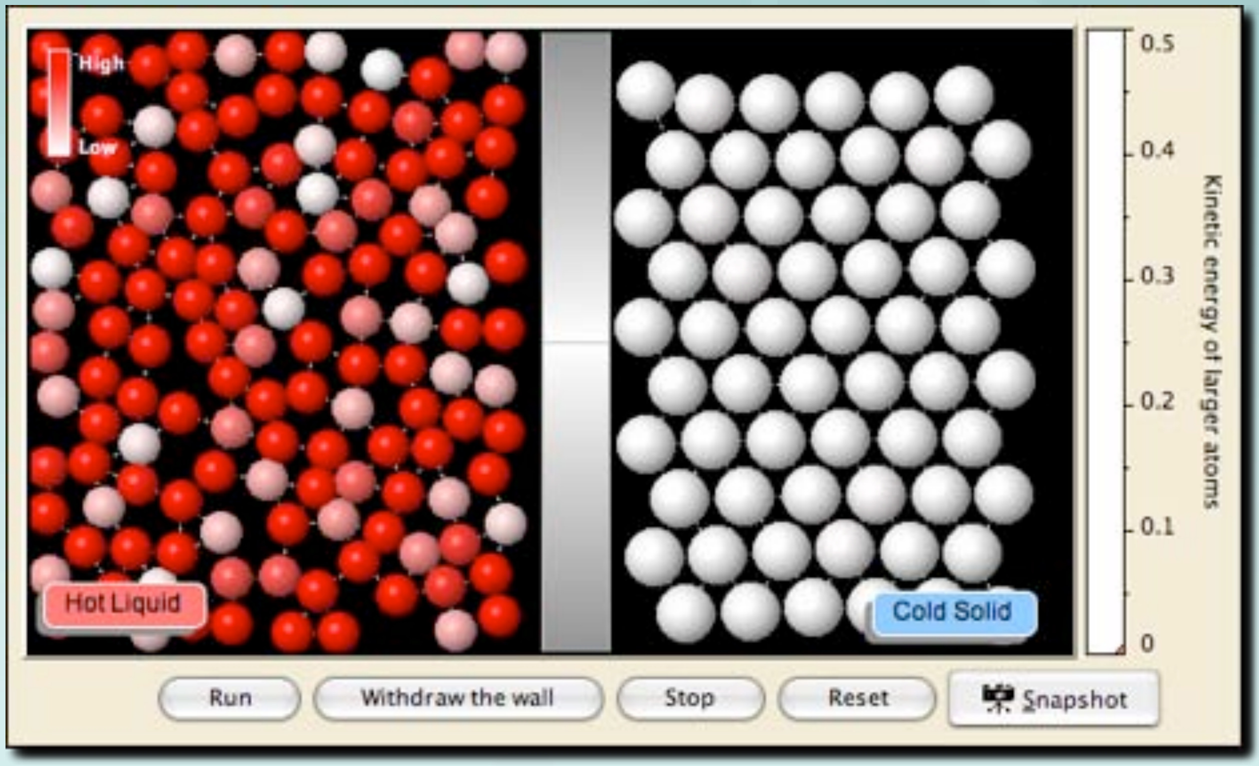

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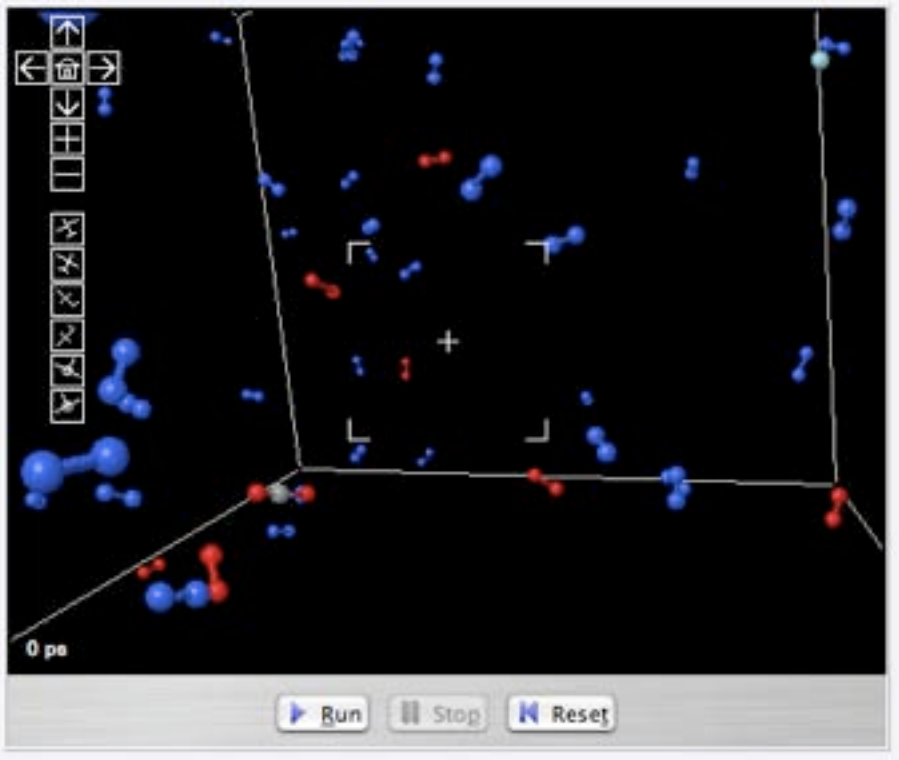

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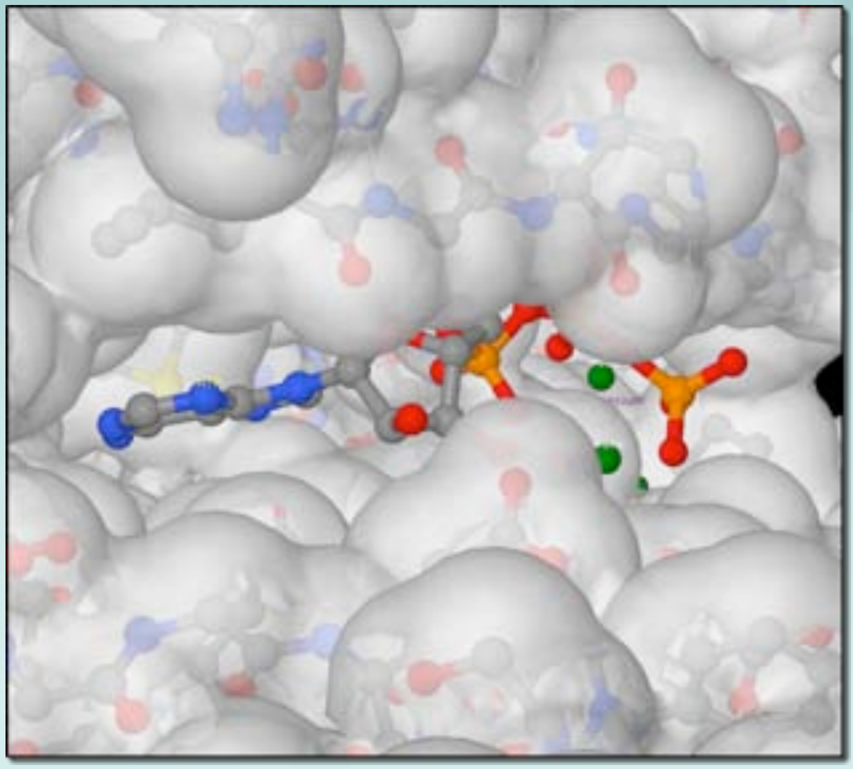

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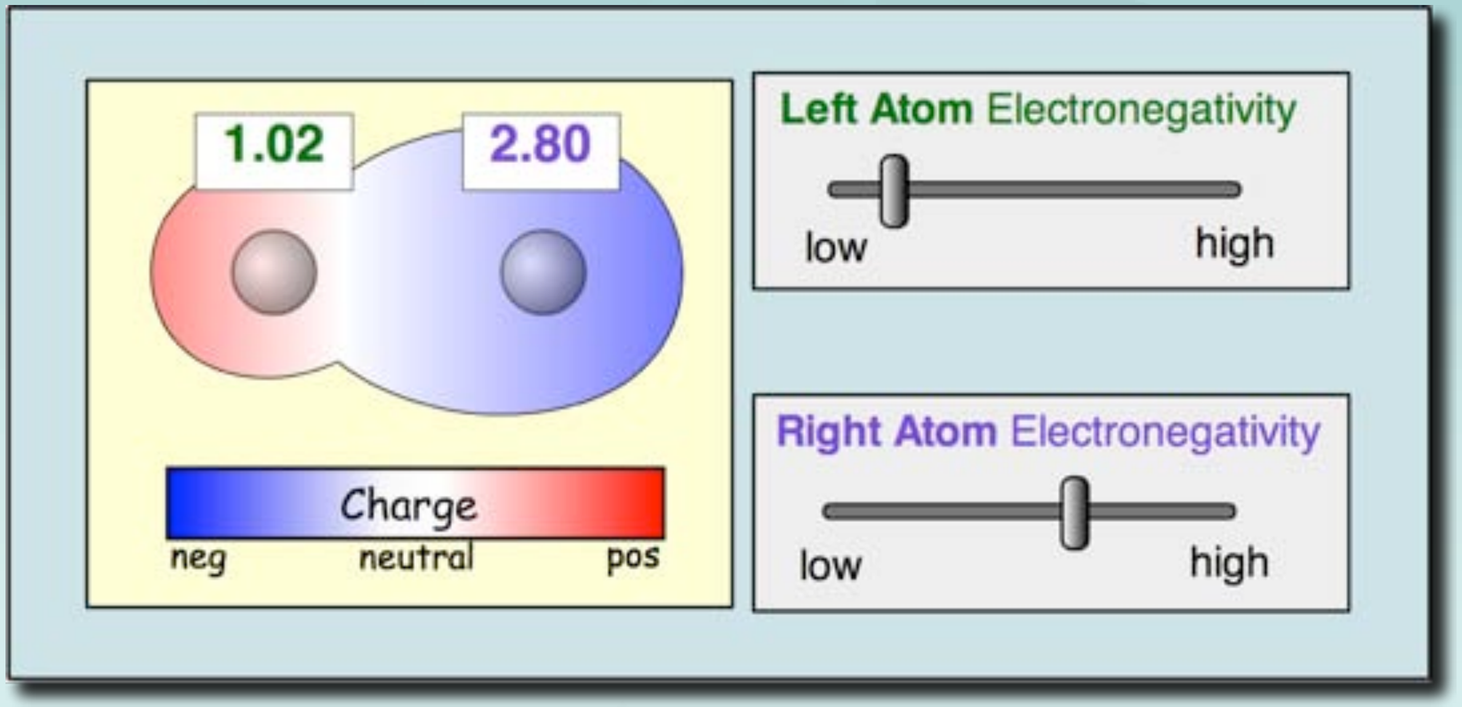

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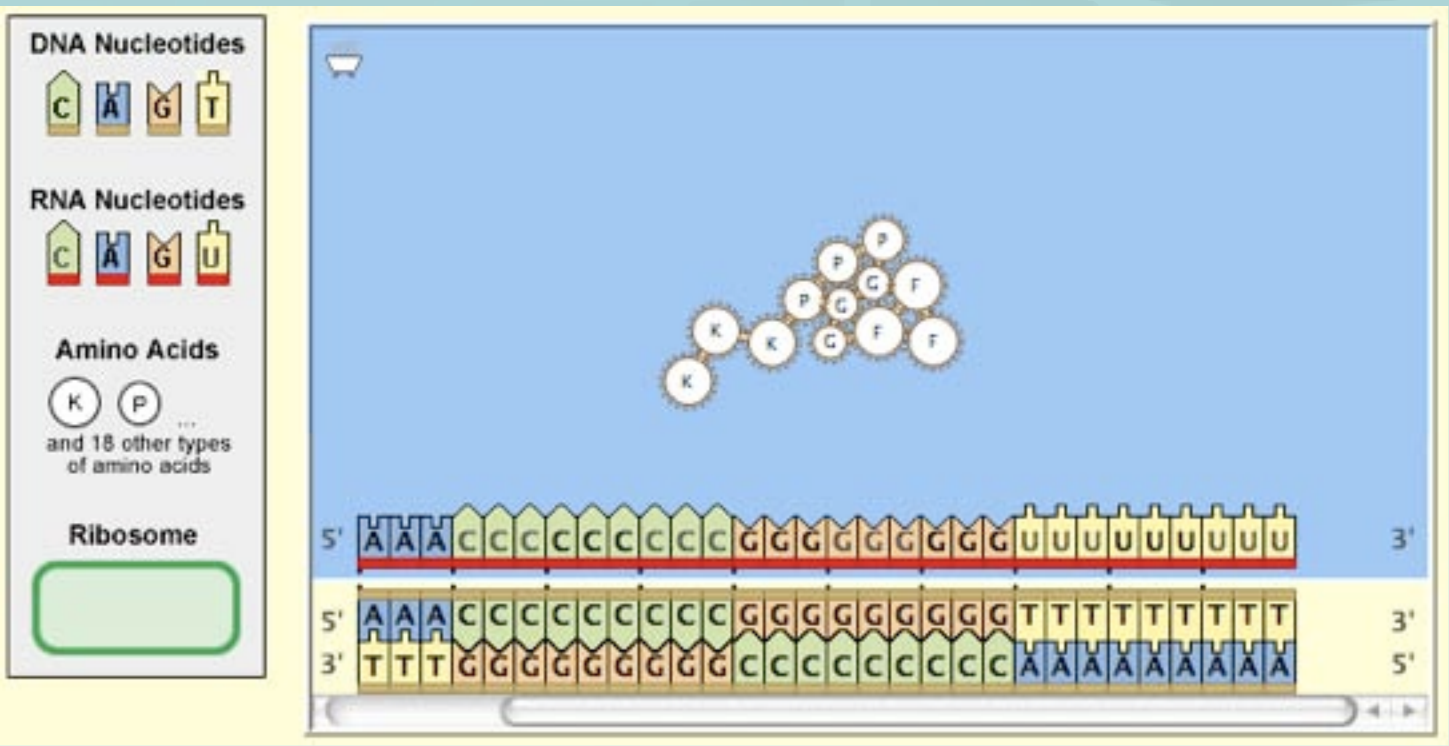
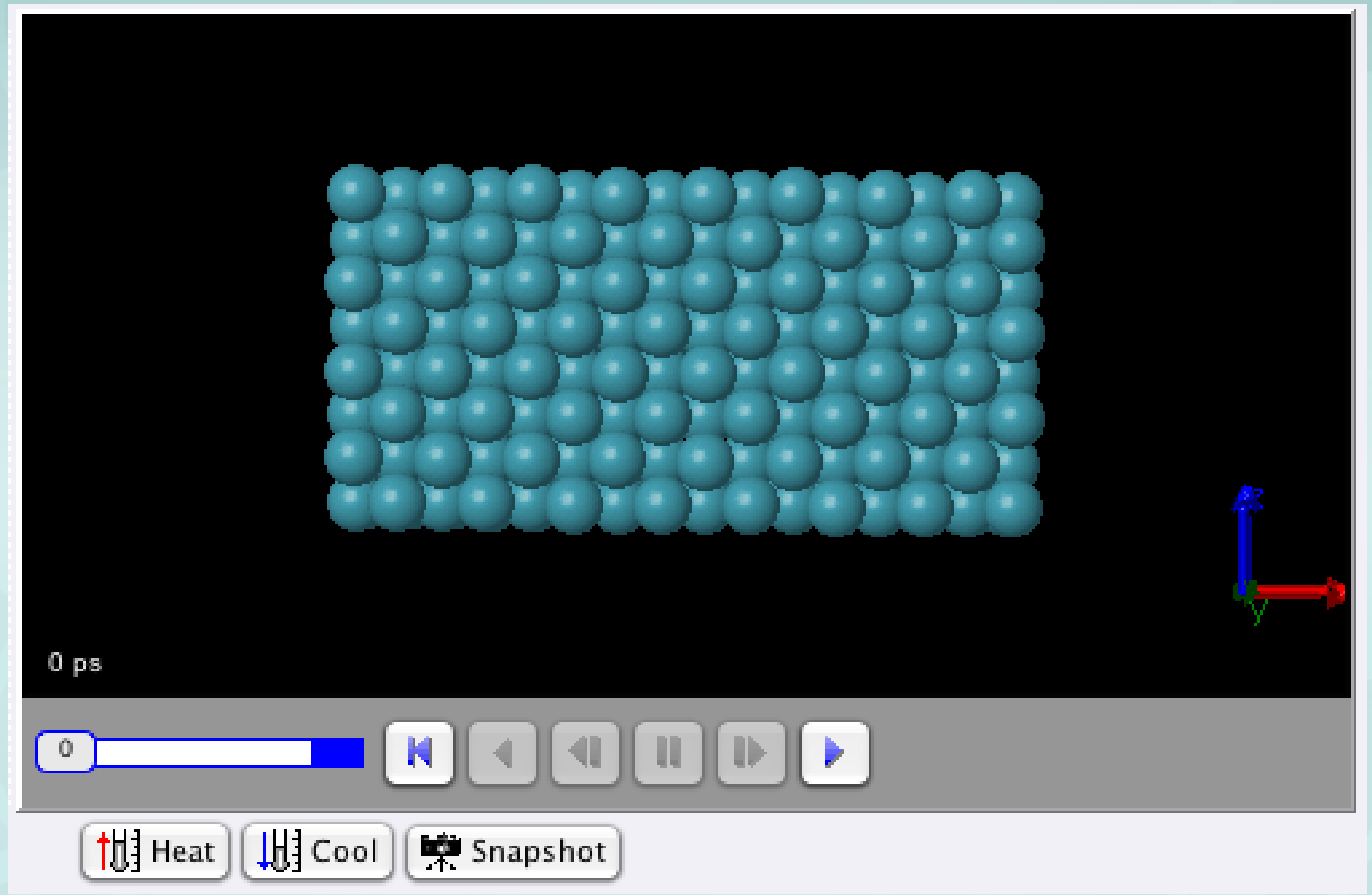
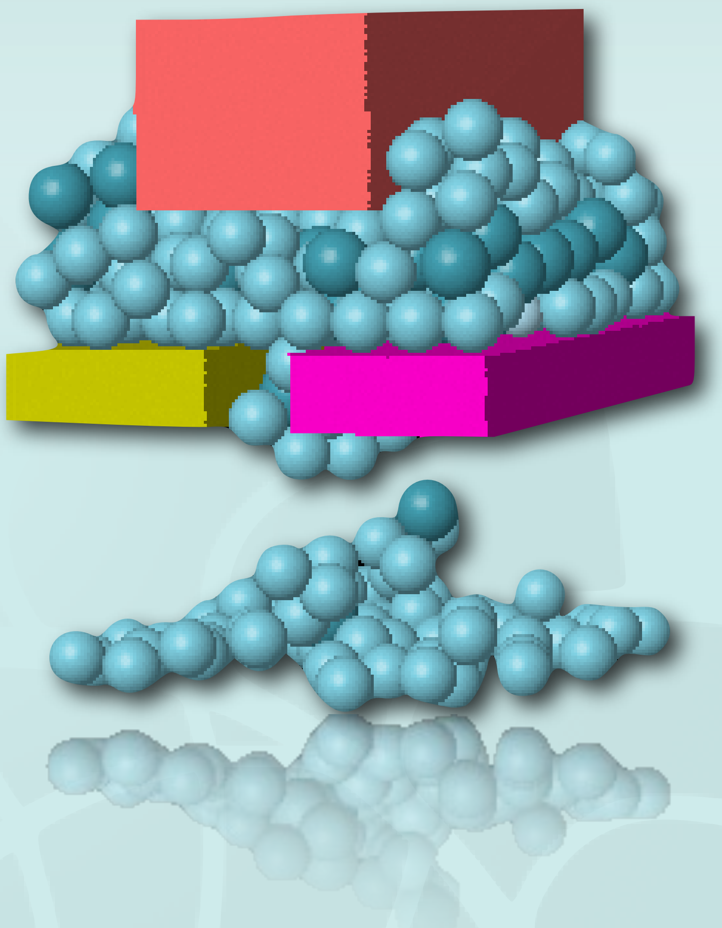


Dynamic Model of Phase Change



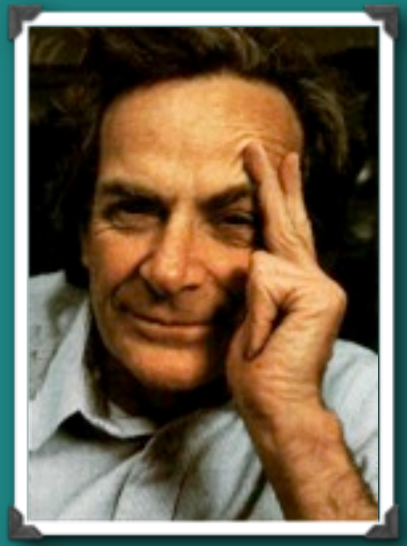
Other Reasons to Use Models

- Help to provide a concrete scaffold for new abstract concepts.
- Can be used in guided inquiry mode.
- Promotes reasoning and supporting ideas with evidence.



A concise summary of the last 100 years of science is that atoms and molecules are 85% of physics, 100% of chemistry and 90% of modern molecular biology.

–Leon Lederman



… all things are made of atoms — little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.

– Richard Feynman

Science of Atoms and Molecules Activities

	Physics	Chemistry	Biology
Motion and Energy	Atoms and Energy	Phase Change	Diffusion, Osmosis, and Active Transport
	Heat and Temperature	Gas Laws	Cellular Respiration
Charge	Electrostatics	Intermolecular Attractions	Four Levels of Protein Structure
	Electricity	Molecular Geometry	Protein Partnering and Function
		Solubility	
Atoms and Molecules	Atomic Structure	Chemical Bonds	Lipids and Carbohydrates
	Newton's Laws at the Atomic Scale	Chemical Reactions and Stoichiometry	Nucleic Acids and Proteins
			DNA to Proteins
Light	Atoms, Excited States, and Photons	Chemical Reactions and Energy	Photosynthesis
	Spectroscopy		

Student Data/Reporting

RI-ITEST DIY: http://ri-itest.diy.concord.org/reports/131/otml?group_id=be8ba548-d701-102b-a487-005056801240&group_lis...

Heat and Temperature (v3)

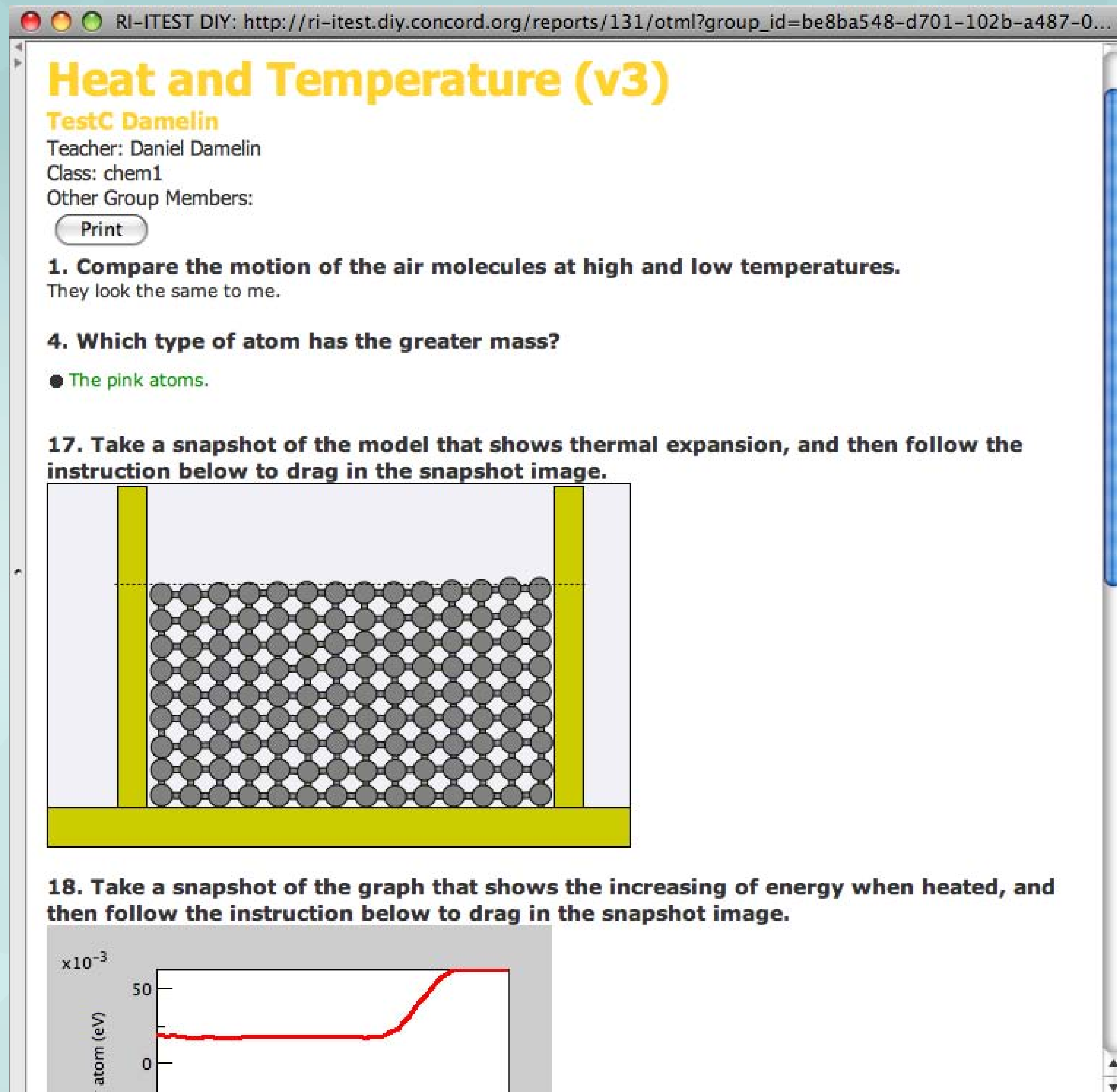
Teacher: Daniel Damelin
Class: chem1

Show students who completed at least 1 % Update List

Print All Users

User	1. Compare the motion of the air ...	2. The temperature of a substance...	3. A substance composed of atoms ...	4. Which type of atom has the gre...	5. The yellow and pink atoms in t...	6. What did you observe about the...	7. If we add another box to the m...	8. Describe how changing the numb...	9. How is the average KE affected...	10. What will happen to the temper...	11. What do you think happens that...	12. W down temper of
		50%		75%		25%	50%	50%		0%		
Report												
TestA Damelin TestB Damelin 38%	They move fast.	• Both the s...	Atom a will be slower.	• The pink a...	Kinetic energy is from the spe...	• Some atoms...	• Be the sam... • Be the sam... • Depend on ...	• Changing n...	The average goes up and down.	No Answer	No Answer	No Answ
TestB Damelin 100%	They move fast.	• Both the s...	Atom a will be slower.	• The pink a...	Kinetic energy is from the	• Some atoms...	• Be the sam... • Be the sam... • Depend	• Changing n...	The average goes up and down.	• They both ...	blah blah blah	blah bla

Student Data/Reporting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Heat and Temperature (v3)

TestC Damelin

Teacher: Daniel Damelin
Class: chem1
Other Group Members:

Print

1. Compare the motion of the air molecules at high and low temperatures.

They look the same to me.

4. Which type of atom has the greater mass?

● The pink atoms.

17. Take a snapshot of the model that shows thermal expansion, and then follow the instruction below to drag in the snapshot image.

18. Take a snapshot of the graph that shows the increasing of energy when heated, and then follow the instruction below to drag in the snapshot image.

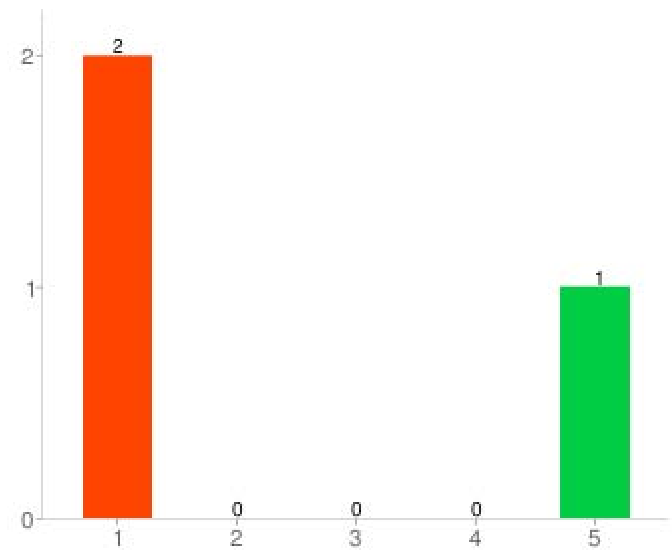
Student Data/Reporting

Question

What did you observe about the kinetic energy (KE) of the atoms? (hint❏)

1. Some atoms have almost no KE.
2. Each atom keeps the same KE.
3. All atoms have the same KE.
4. An atom's KE is changing all the time.
5. Both A and D are true.

Frequency Graph

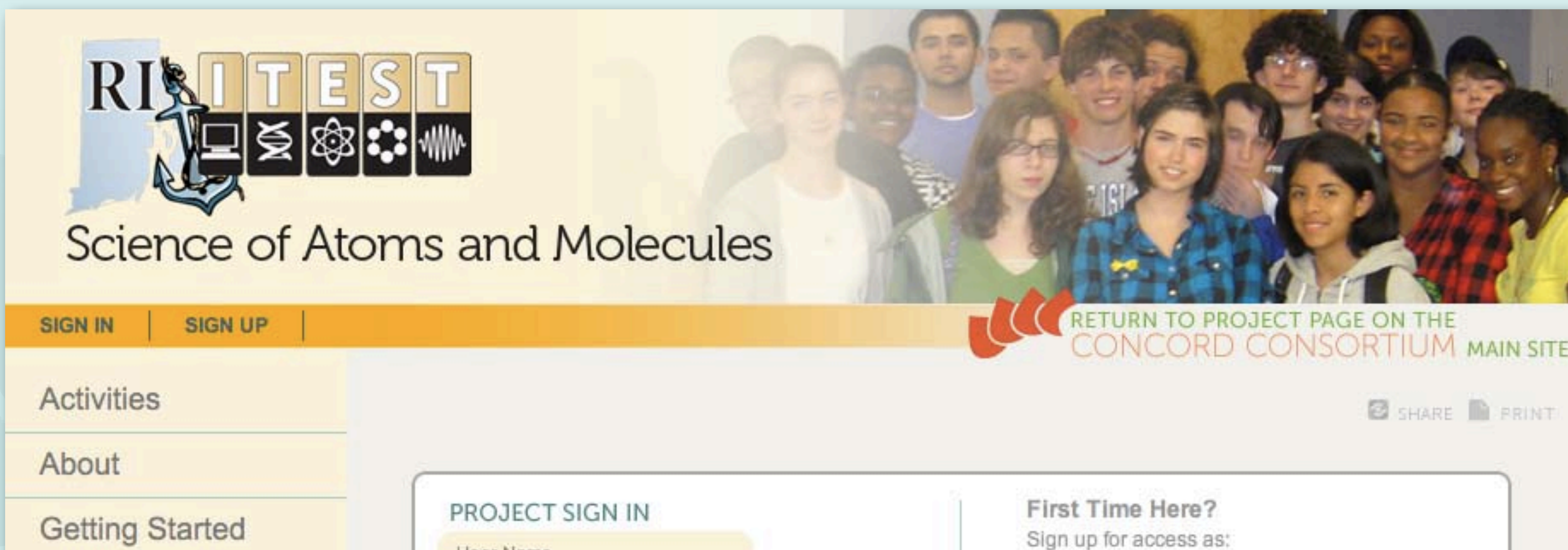


Answers

TestA Damelin	● Some atoms have almost no KE.
TestB Damelin	● Some atoms have almost no KE.
TestC Damelin	● Both A and D are true.
Dan Test	No Answer

Previewing Models and Using the Portal

- Go to: http://ri-itest.concord.org
- Click on the Go to the Portal button.
- Click on the "Activities" link.
- Click the try button on an activity.



Inquiry is Key

- Going deeper can simplify science.
  - Most scientific phenomena can be explained by fundamental ideas of energy, force, the atomic nature of matter, and equilibrium.
  - Science through this lens is more connected - less individual facts to "memorize."
- Conceptual understanding is the goal.
- Utilize interactive models, to allow inquiry at the atomic level.
- Teachers are essential for inquiry approach to work.

Professional Development Goals

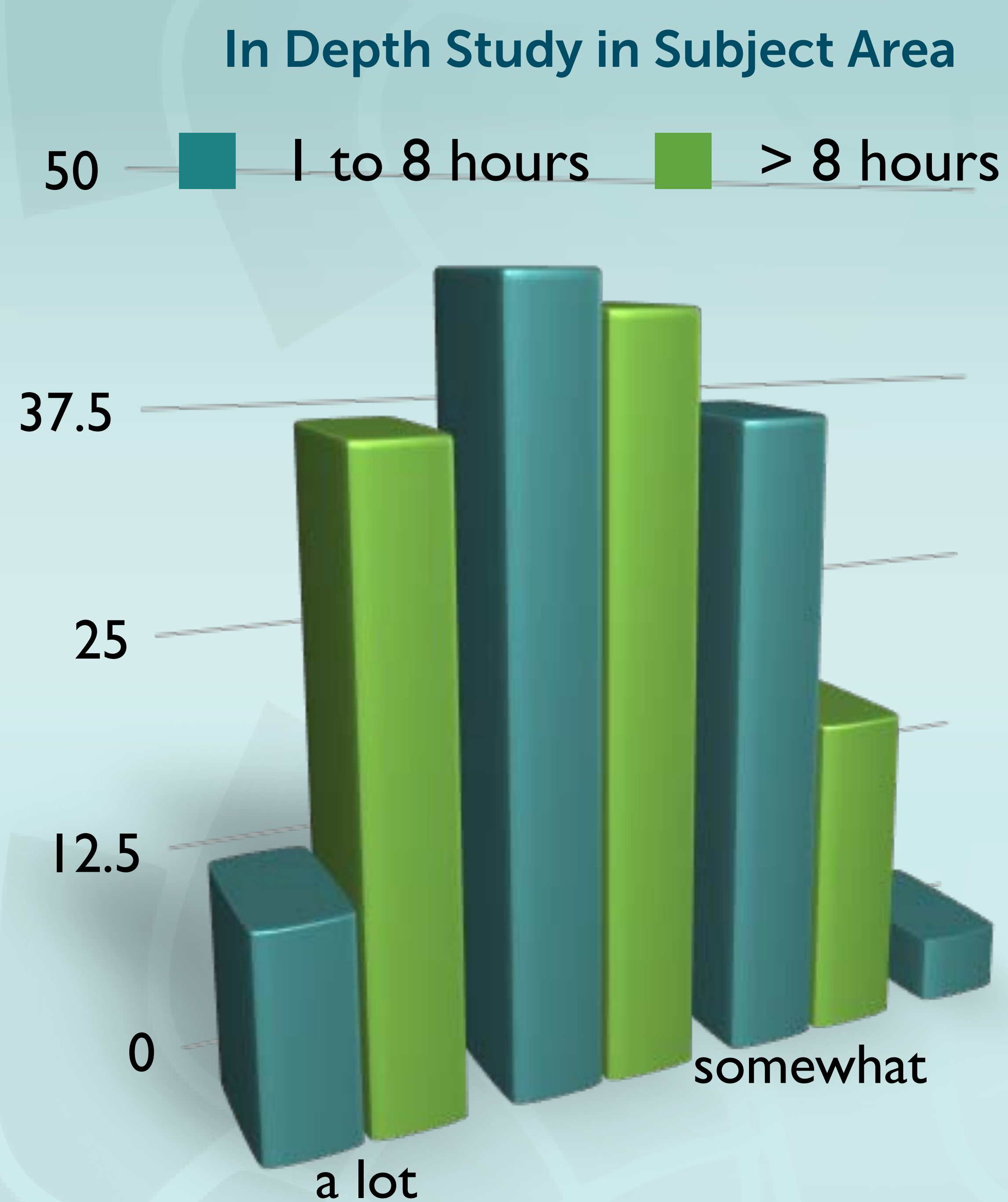
- Understand the science of atoms and molecules (SAM) and how it connects with current curriculum.
- Implement SAM learning activities in current curricula.
- Provide related IT career information.
- Utilize guided inquiry of SAM models in teaching.

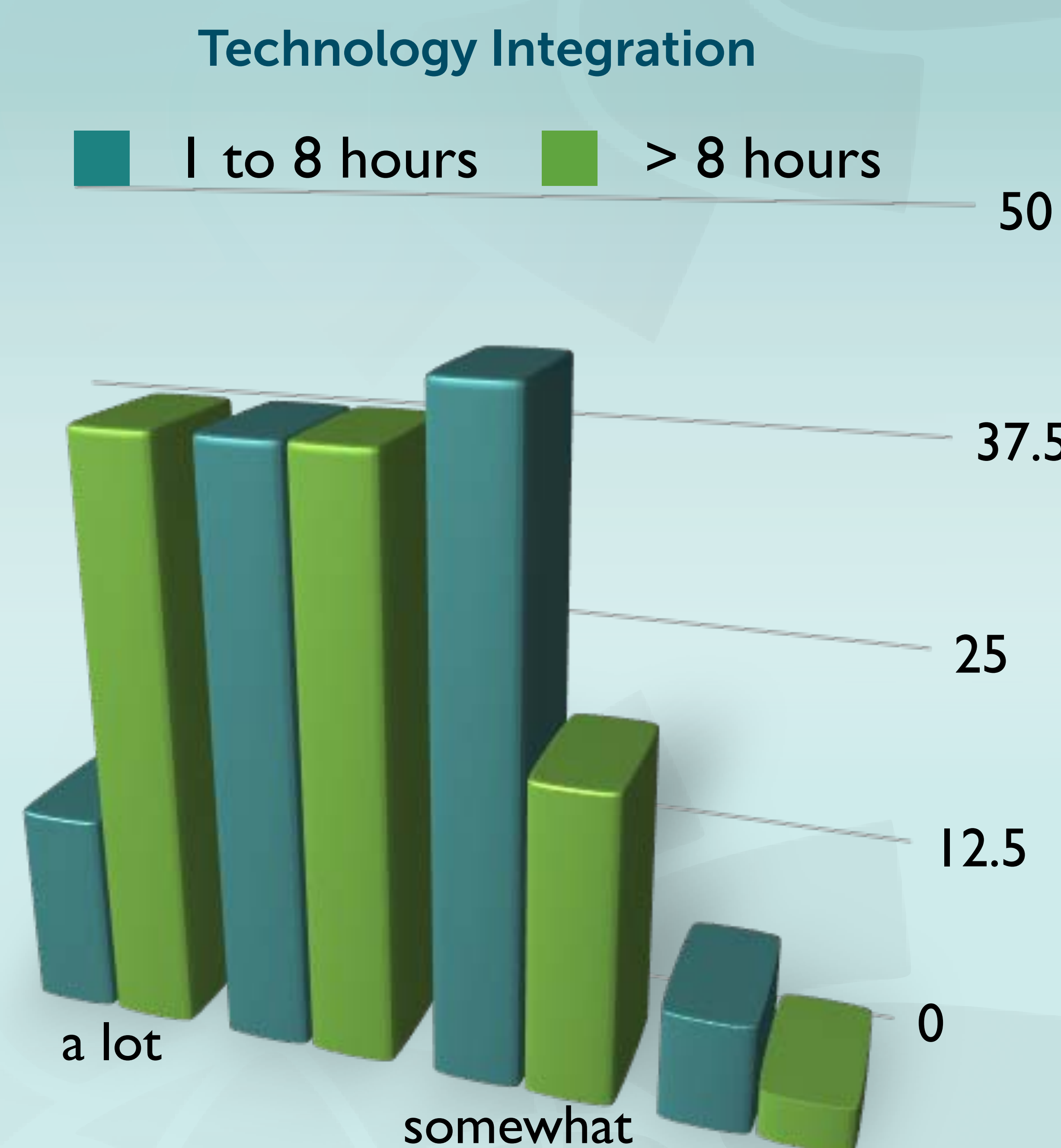
Factors affecting successful PD

- community (either local or through social networking)
- subject matter portion of PD must match teachers' current curriculum
- focusing on student understanding

- AERA, "Research Points" (2005)

More PD in a Concentrated Area has Positive Outcomes





- DOE National Center for Education Statistics 2001

Project Design

120 hours of PD spread over an online course, face-to-face meetings, and two summer institutes. Graduate credit and stipend earned by teachers who successfully complete each year.

	2008			2009			2010			
	Sprng	Sum	Fall	Sprng	Sum	Fall	Sprng	Sum	Fall	Totals
Cohort 1										
Summer workshop		30			30					60
Online course			12	12		12				36
Weekend workshops			8	8		8				24
Cohort 2										
Summer workshop					30			30		60
Online course						12	12		12	36
Weekend workshops						8	8		8	24

Molecular Concept Inventory (MCI)

- Pre-post test of student and teacher knowledge.
- Students took subject specific test.
- Teachers took combination of student MCI tests.

Example MCI Test Item

33. Imagine a cell that has a membrane through which potassium ions freely enter and leave. Suppose this cell contains a high concentration of potassium and is put in distilled water that has no potassium. Which is the BEST description of what will happen?

a) All of the potassium ions will leave the cell.

b) Potassium ions will move only from high concentration to low concentration.

c) Potassium ions will leave the cell until there is the same concentration of salt inside and outside the cell.

d) (correct answer) Potassium ions will reach a point when they will continuously enter and leave the cell at equal rates.

RI-ITEST Participants

28 Participating Schools	
Burrillville High School	Lincoln High School
Central Falls High School	Mount Pleasant High School
Classical High School	Narragansett High School
Community College of Rhode Island	North Smithfield High School
Cooley High School	Ocean Tides High School
Coventry High School	Pilgrim High School
Cranston West High School	Portsmouth High School
Cumberland High School	Rogers High School
Dighton-Rehoboth High School	Shea High School
Dr. Jorge Alvarez High School	South Kingstown High School
E-Cubed Academy	Textron Academy
East Providence High School	Tiverton High School
Exeter-West Greenwich High School	Toll Gate High School
LaSalle Academy	Woonsocket High School

Research Findings - Some Stats

- Since project started 220 teachers registered in portal, with over 17,000 students in those classes.
- Last year about 4,600 students ran activities, generating 17,000 reports.
- Doesn't pick up LCD only usage.

Student Impact

Do understand science concepts better after using the RI-ITEST program?

- **59% yes**

Do you feel that you are more interested in science as a result of working with RI-ITEST?

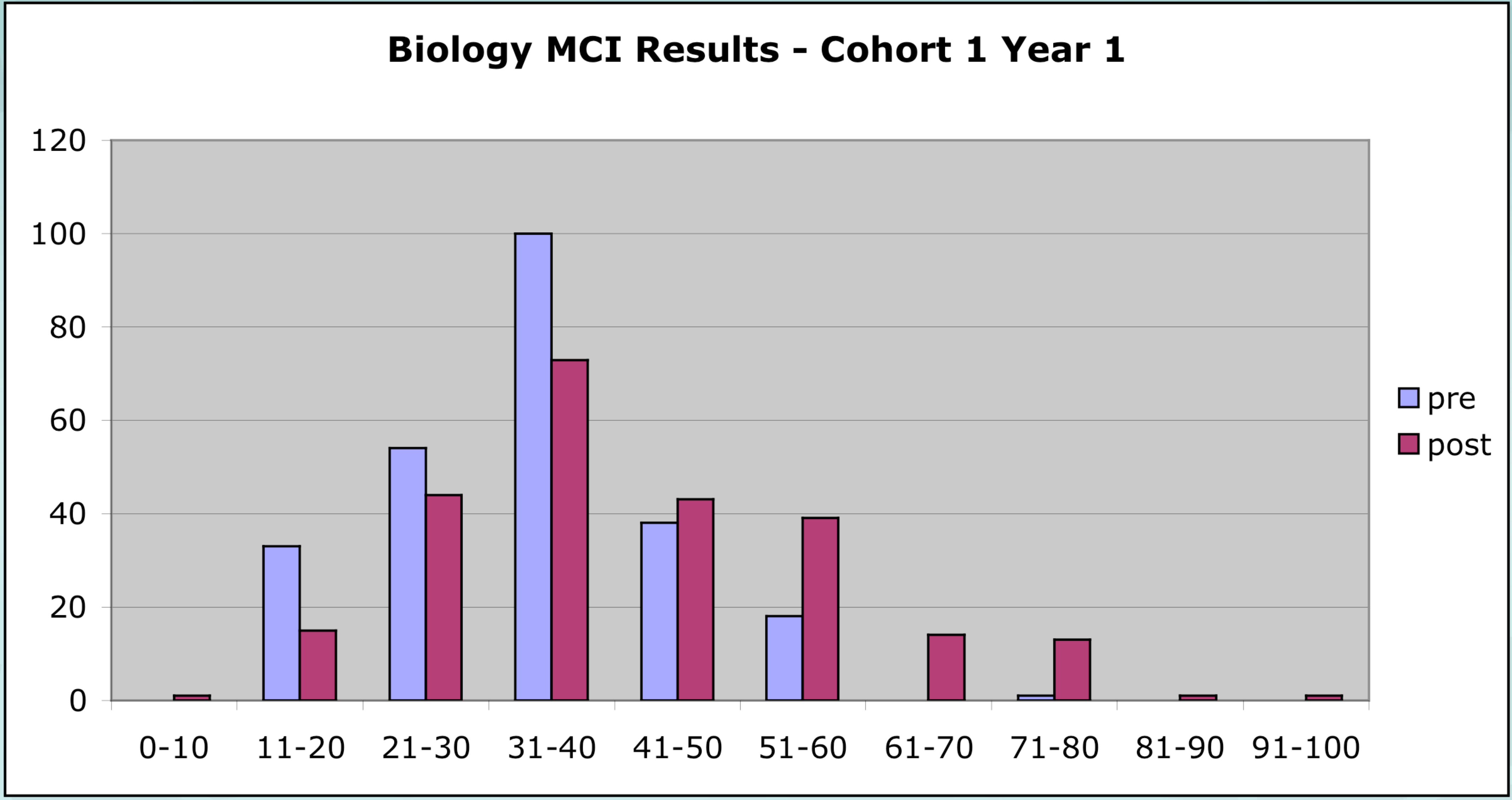
- **29% yes**

Student Impact

How did using this program impact your interest in taking other science courses in high school or beyond?

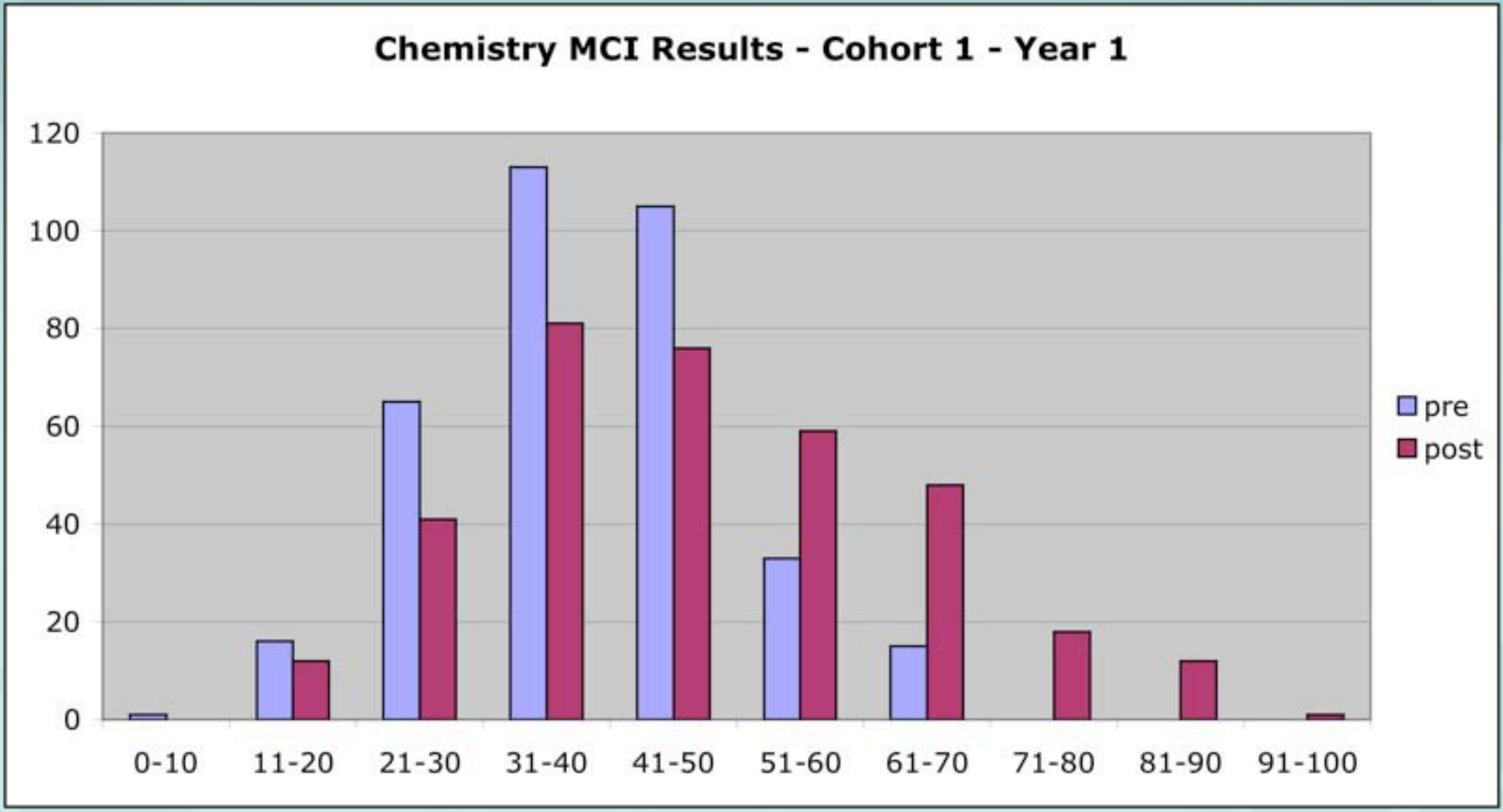
	n	Percentage Responding
1 – SAM strongly impacted student's interest in taking additional science courses	5	0.58%
2 – SAM had a positive impact on student's taking additional science courses	114	13.26%
3 – SAM had no impact on student's taking additional science courses	395	45.93%
4 – SAM had a negative impact on student's taking additional science courses	41	4.77%
0 – Student did not answer the question and/or offered information that had no bearing on the answer	302	35.12%

MCI Results
Cohort 1 - Bio



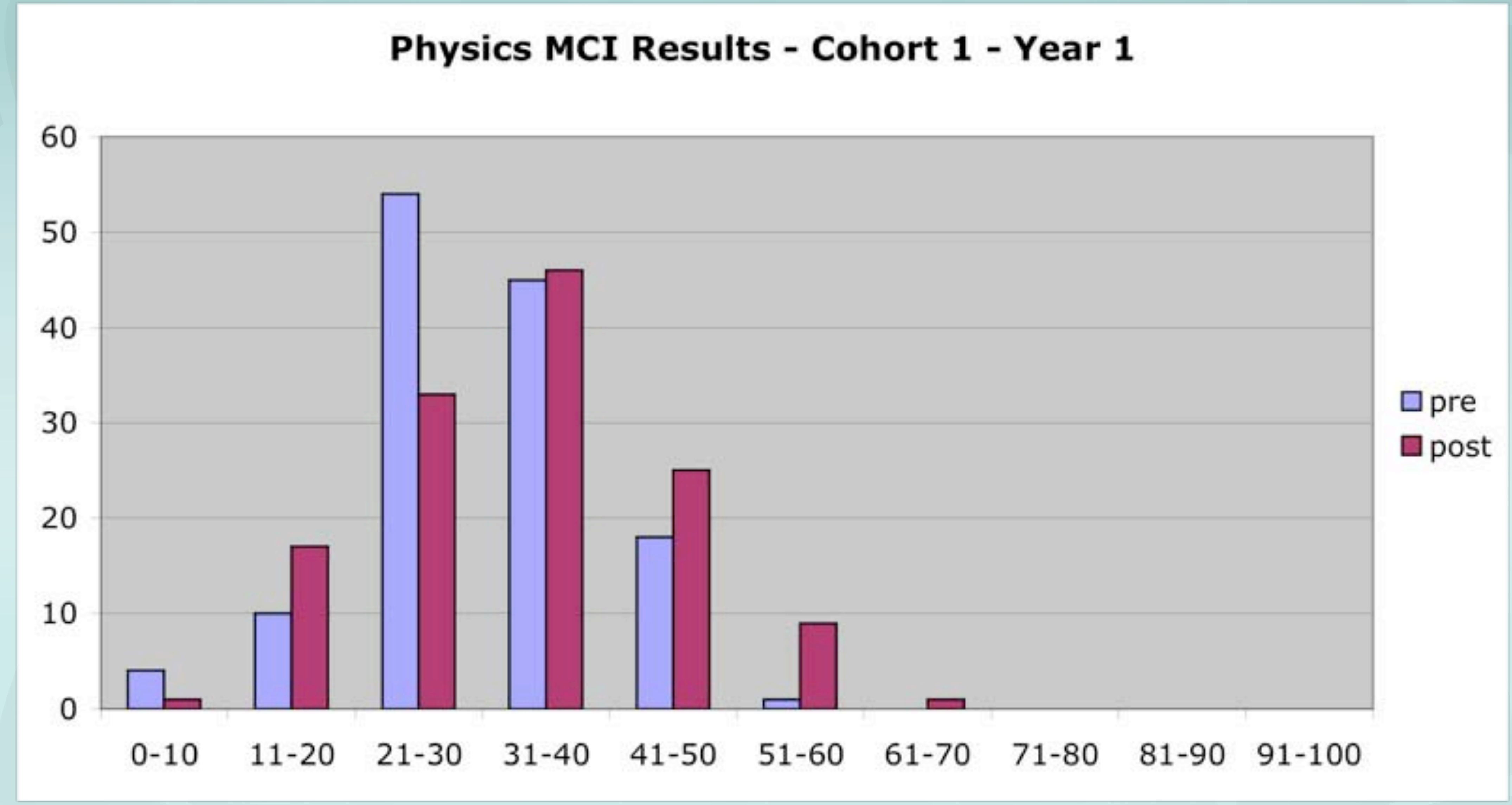
Group	Pre-test mean	Post-test mean	n	p-value based on paired t-test	Cohen's d	Effect size
Biology	34%	42%	244	1.9e-15	0.6	Moderate

MCI Results
Cohort 1 - Chem



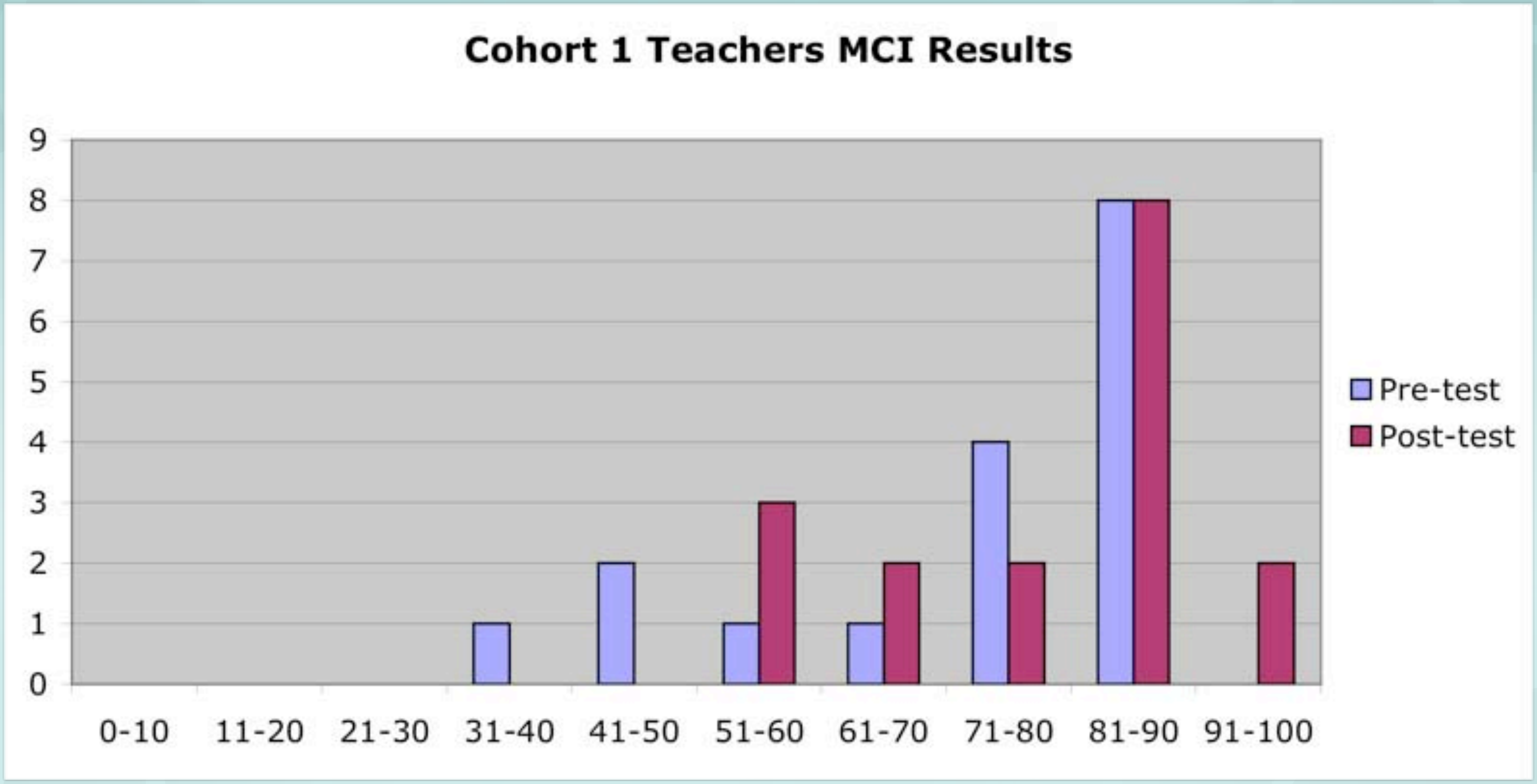
Group	Pre-test mean	Post-test mean	n	p-value based on paired t-test	Cohen's d	Effect size
Chemistry	39%	47%	348	7.8e-32	0.6	Moderate

MCI Results
Cohort 1 - Physics



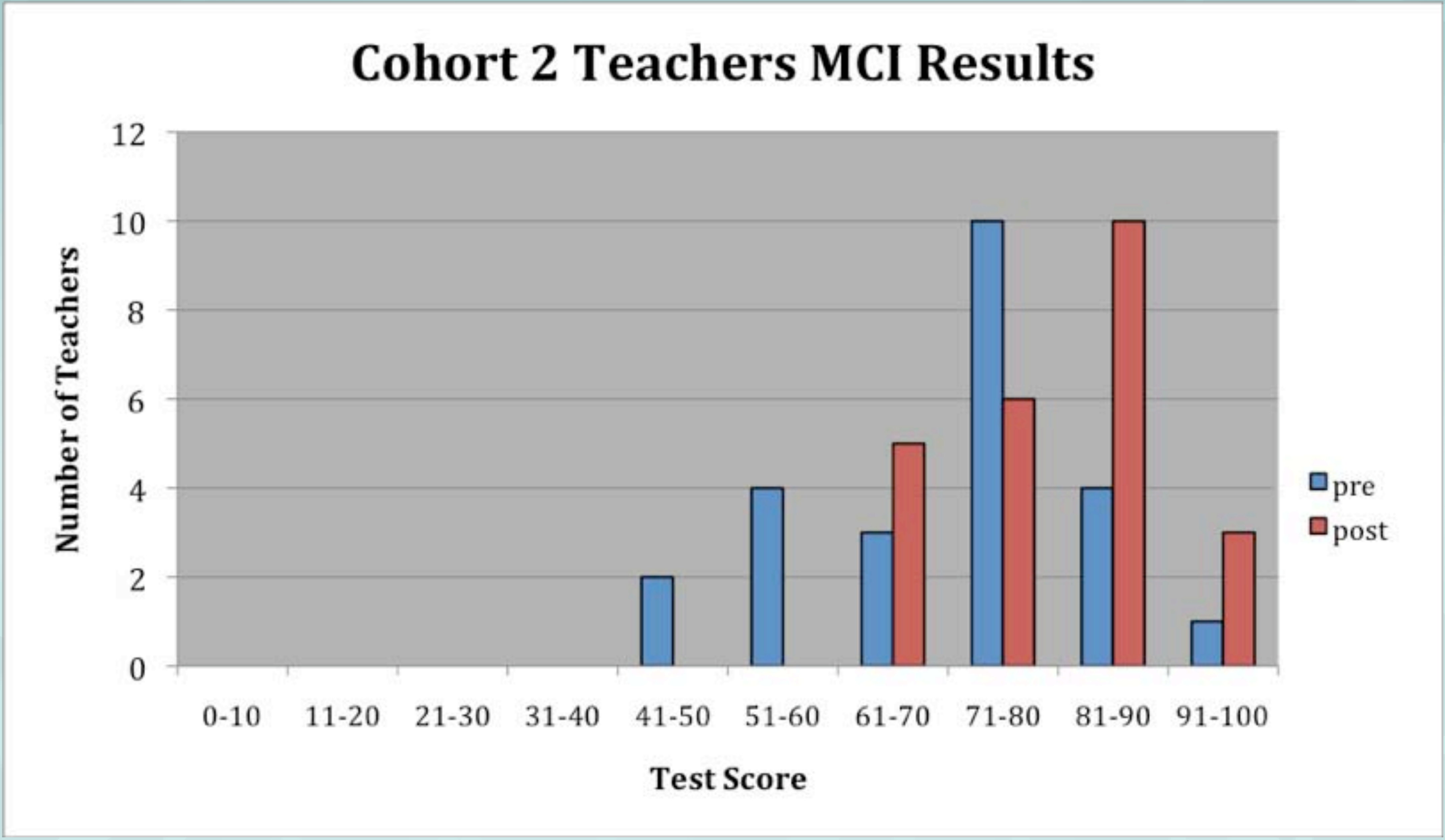
Group	Pre-test mean	Post-test mean	n	p-value based on paired t-test	Cohen's d	Effect size
Physics	32%	35%	140	0.0015	0.3	Small

MCI Results
Cohort 1 - Teachers



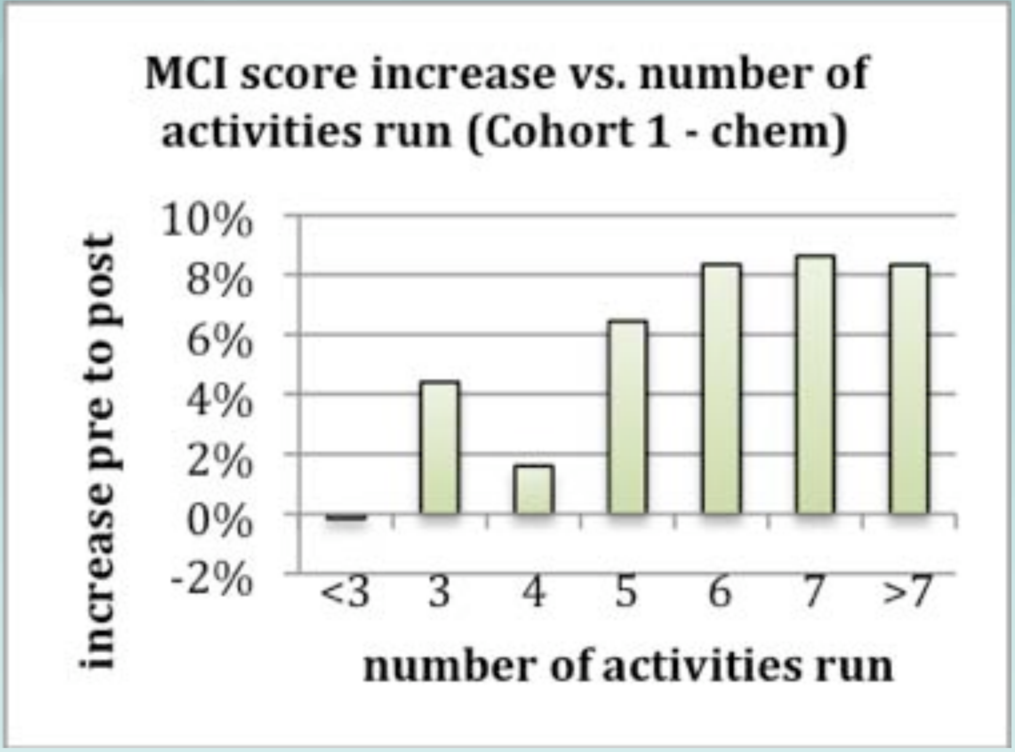
Group	Pre-test mean	Post-test mean	n	p-value based on paired t-test	Cohen's d	Effect size
Teachers	73%	76%	17	0.030	0.2	Small

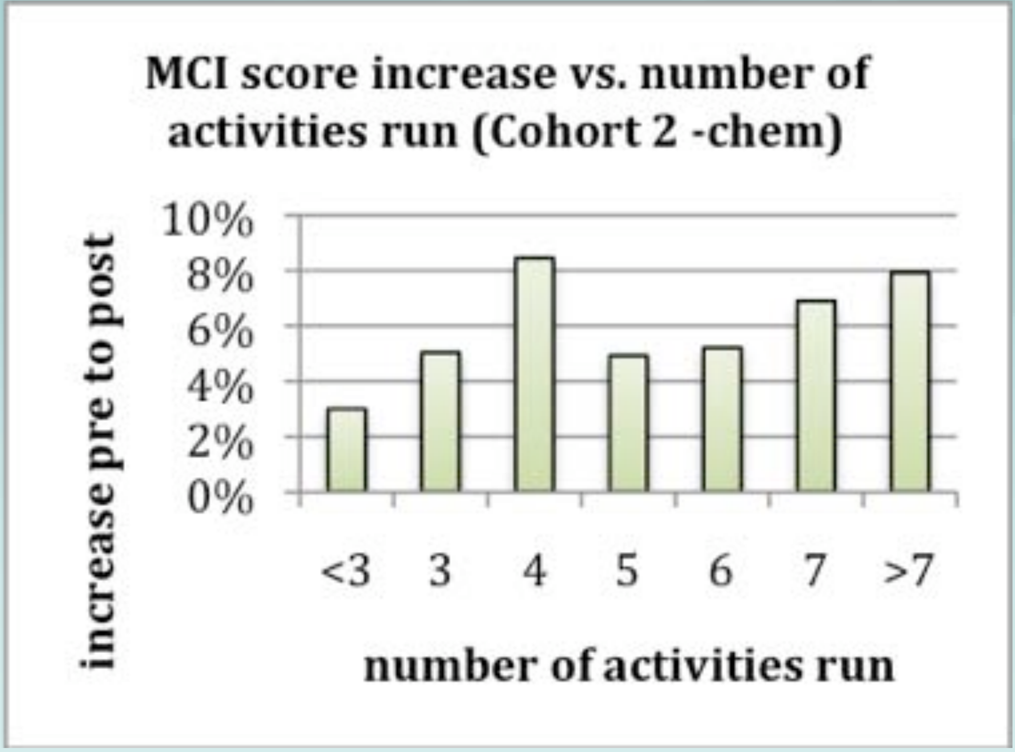
MCI Results
Cohort 2 - Teachers

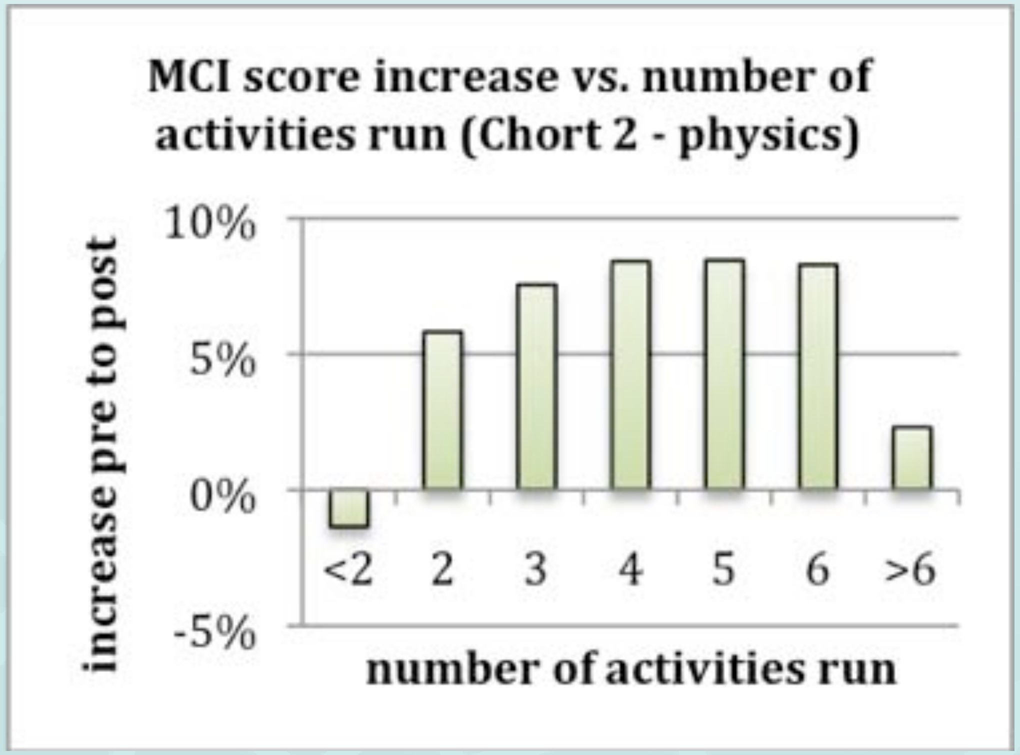


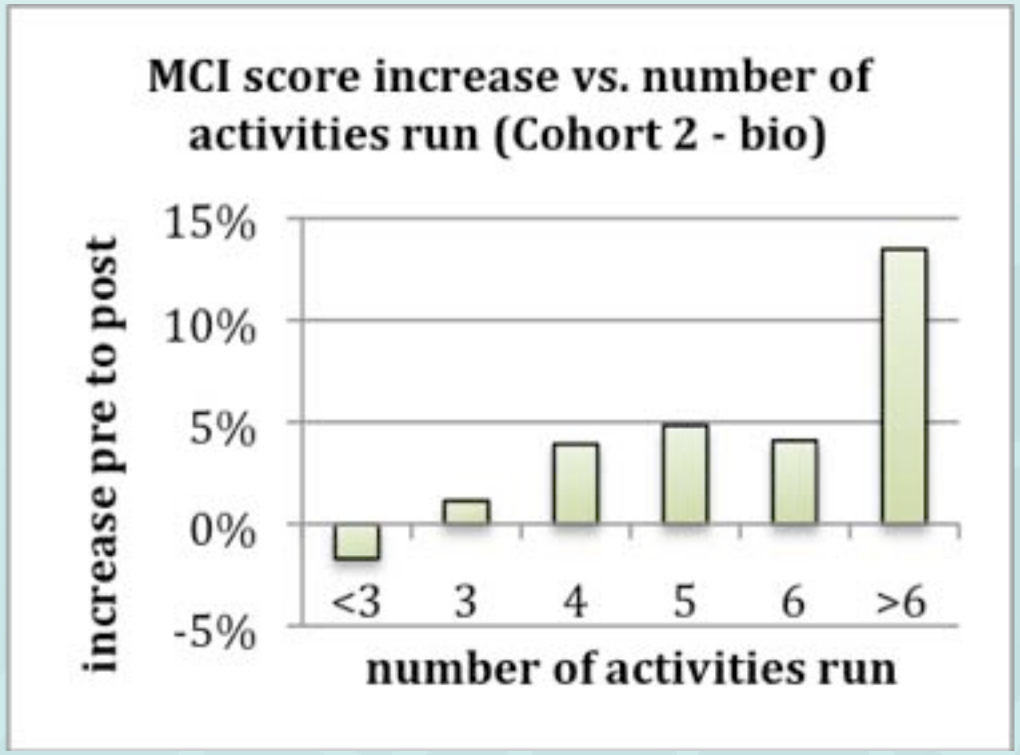
Cohort 2 Group	Pre-test mean	Post-test mean	n	p-value based on paired t-test	Cohen's d	Effect size
Teachers	72%	80%	24	5.3e-6	0.8	Large

Score increases related to number of SAM activities completed









Student Quotes

"It can be difficult to visualize some of the more complex concepts of chemistry, so the visual models can really help [me] understand these concepts."

Student Quotes

“The best part of using the SAM tools was to be able to see things that we would not normally be able to see with labs. The tools were fun and easy to use, the instructions were straightforward and I found it interesting to watch the simulations.”

Teacher Quotes of Their “Best Experiences”

“In a lesson on electrostatics (not the RI-ITEST model) a student referred back to something he had learned while doing a RI-ITEST activity. The classroom discussion went far more smoothly as a result of the students having learned about atomic structure via the interactive models.

Teacher Quotes of Their “Best Experiences”

“Students begging to do more units on the computer … [and] … writing more than they usually do in response to something they did only moments before.”

Contact Info

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Explore other projects at:
http://www.concord.org/projects