



The **Concord**
Consortium

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

Dan Damelin, The Concord Consortium

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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

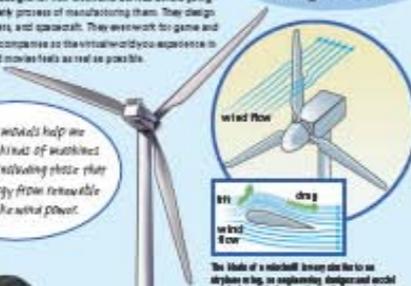
- Improve science content knowledge.
- Increase student awareness of related computer modeling careers.
- Bring together a more connected understanding of how the world of atoms and molecules links physics, chemistry, and biology.

PHYSICS

Scientists working in physics-related fields use computer models to understand the orbits and fate of the universe. They use models to test designs for new electronic devices before going through the costly process of manufacturing them. They design airplanes, rockets, and spacecraft. They even work for game and special effects companies as the virtual worlds you experience in 3D gaming and movies feel as real as possible.

Engineer

Computer models help me to design all kinds of machines and gadgets, including those that provide energy from renewable sources like wind power.



The blades of a windmill barely rise far to the air when they're in engineering. Computer models can be applied to test energy.

Other Careers in Physics

Job Title	Description	Education Level Required	Average Salary
Electronic Technician	Install, adjust, calibrate, troubleshoot, maintain, repair, and test electronic equipment.	High school diploma	\$31,500
Mechanician	Study the mechanical parts of airplanes, motors, and processes to perform a service.	Bachelor's degree	\$71,100
Mechanical Engineer	Research, design, develop, manufacture, test, and maintain engines, machines, and other mechanical devices.	Bachelor's degree	\$83,900
Behavioral Scientist (Data Scientist)	Analyze user trends and their design, use, and engagement with various devices.	Bachelor's degree	\$79,700
Astronomer	Observe, measure, interpret, and analyze the light to explain celestial objects and phenomena. Develop the instruments and techniques used to observe and collect astronomical data.	Ph.D.	\$81,700

CHEMISTRY

Scientists working in chemistry-related fields use computer models to design molecules that can interact with our cells. They help companies find new materials like gold, diamonds, and oil. They help model climate change and predict the results of changes in regulations that affect the cleanliness of our air and water. The new field of nanotechnology relies on computer models to guide the design of objects that are too small to see even with a microscope. Objects that will ultimately have unique electrical or chemical properties.

Drug Designer

Using computer models I design and predict the safety of possible molecules. Some day, cancer may be cured this way.



Other Careers in Chemistry

Job Title	Description	Education Level Required	Average Salary
Process Control Technician	Monitors stress by adjusting and controlling and analyzing.	2-year degree	\$33,100
Materials Scientist	Research chemical and other things used in the development of new and improved plastics, fibers, paints, drugs, cosmetics, electronic components, and thousands of other products.	Bachelor's degree	\$74,600
Environmental Engineer	Develop solutions to environmental problems, including air quality and pollution control, recycling, noise control, and public health issues.	Bachelor's degree	\$81,900
Food Scientist	Develop new techniques for processing, packaging, storing, and distributing food.	Master's degree	\$81,000
Computational Chemist (Drug Designer)	Design new molecules to solve problems in medicine and other fields. Model molecular behavior or interactions to help understand fundamental principles of chemistry.	Ph.D.	\$84,700

A job title is people specially designed to find a DNA molecule a base. Using an system within these bits can design and use to produce many molecules.

BIOLOGY

Scientists working in biology-related fields use computer models to predict the spread of disease. They use models to understand how the body works at many different levels, from the way breathing is affected by pollution to the specific details of how a gene controls a signal to the brain. Biologists use computer models to decide what organisms to introduce and what changes to make to restore the environment to a state of ecological balance. With the help of computer models, huge amounts of data in our genes are now being analyzed to better understand genetic disorders and how to treat them.

Wildlife Biologist

Computer models help predict the effects of new development will have on habitats and ecosystems.



Other Careers in Biology

Job Title	Description	Education Level Required	Average Salary
Lab Technician	Prepare specimens, operate mechanical equipment and perform manual tasks with detailed instructions.	Associate's degree	\$22,600
Biomedical Engineer	Apply knowledge of engineering, biology, and biomedical principles to the design, development and analysis of biological and health systems and products.	Bachelor's degree	\$71,700
System Biologist	Investigate and describe the complex interactions between, such as, molecules, cells, and the way organisms are programmed to control.	Master's degree	\$84,900
Wildlife Biologist	Study animals and wildlife, including behavior, diseases, and life processes.	Ph.D.	\$81,100
Genetic Researcher	Conduct biomedical research to determine genetic causes, disease, drug, and treatment procedures.	Ph.D.	\$81,900

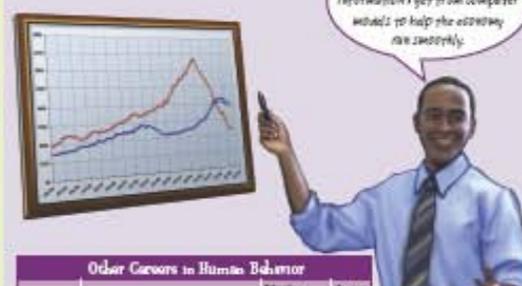
A map showing regions that have been labeled by all 10 possible species. Using this cell I find that data into a computer model that can help find places for restoring habitats to the wild natural.

HUMAN BEHAVIOR

The field of human behavior covers a wide range of topics from business management to the study of how the brain functions. Some scientists model social interactions between large populations of people while others create models to help them predict the direction of the stock market. Robotics designers who develop human-like robots model the way we move and even the way we think and express emotion.

Economist

Corporations and governments use the information I get from computer models to help the economy run smoothly.



Other Careers in Human Behavior

Job Title	Description	Education Level Required	Average Salary
Analyst	Develop financial plans, analyze, and help organizations determine and analyze financial operations, investments, and risks.	Bachelor's degree	\$61,900
Market Research Analyst	High computer concentration for types of products, such as people, mass, and consumer goods.	Bachelor's degree	\$61,300
Urban Planner	Develop plans for the use of land and the growth and distribution of urban, suburban, and rural communities.	Master's degree	\$64,000
Economist	Conduct research, collect and analyze data, create economic models, and develop forecasts.	Master's or Ph.D.	\$77,000
Biologist	Study complex and social behavior, including how people react to the spread of technology, health, spreading, strong and social interactions.	Master's or Ph.D.	\$61,300

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

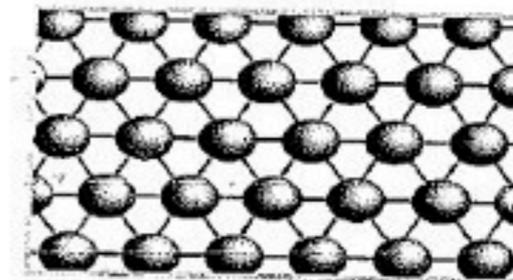
Within all matter there is a constant competition between temperature and intermolecular forces. The kinetic energy from temperature tends to push molecules apart. When temperature wins the competition, molecules fly apart and you have a gas. The intermolecular forces tend to bring molecules together. 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

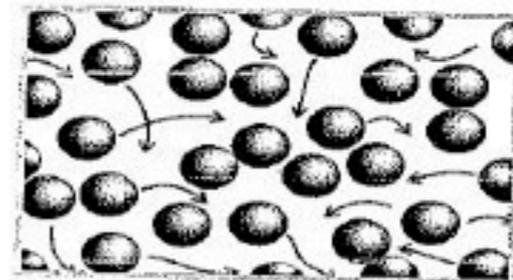
Iron is a solid at room temperature. Water is a liquid at room temperature. This tells you that the intermolecular forces between iron atoms are stronger than those between water molecules. In fact, iron is used for building things because it is so strong. The strength of solid iron is another effect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

Temperature

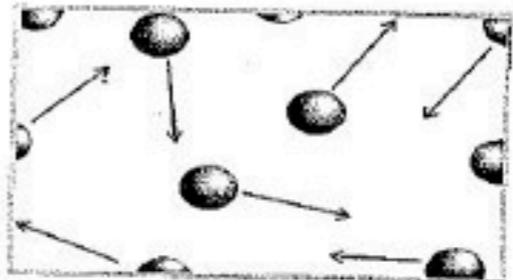
As the temperature changes, the balance between temperature and intermolecular forces changes. At temperatures below 0°C, the intermolecular forces in water are strong enough to overcome temperature and water becomes solid (ice).



Solid



Liquid



Gas

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

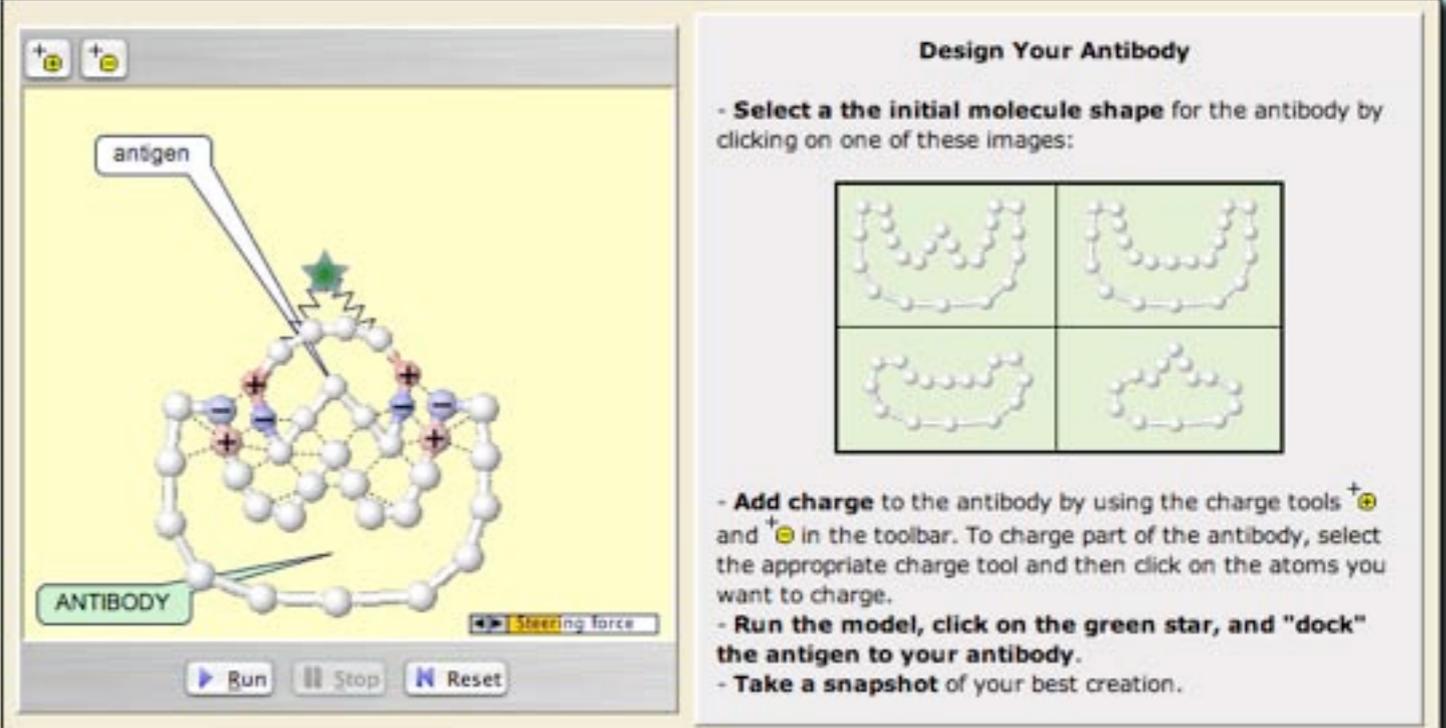
The Molecular Workbench – a molecular dynamics tool.

- 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

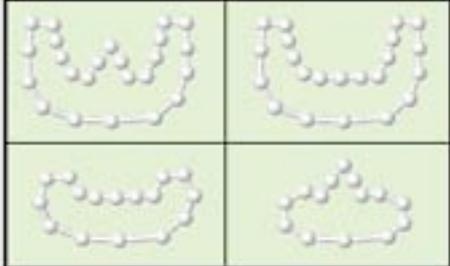
- 2D and 3D Molecular Dynamics Models
- 3D Exploration of Static Molecular Representation
- Flash based models
- Abstract dynamic models of DNA, RNA and proteins



The screenshot shows a software interface for designing an antibody. On the left, a 3D ball-and-stick model of an antibody is shown with a green star labeled 'antigen' docked on its surface. The antibody is labeled 'ANTIBODY' and has a 'Steering force' slider. At the bottom are 'Run', 'Stop', and 'Reset' buttons. On the right, a panel titled 'Design Your Antibody' provides instructions:

Design Your Antibody

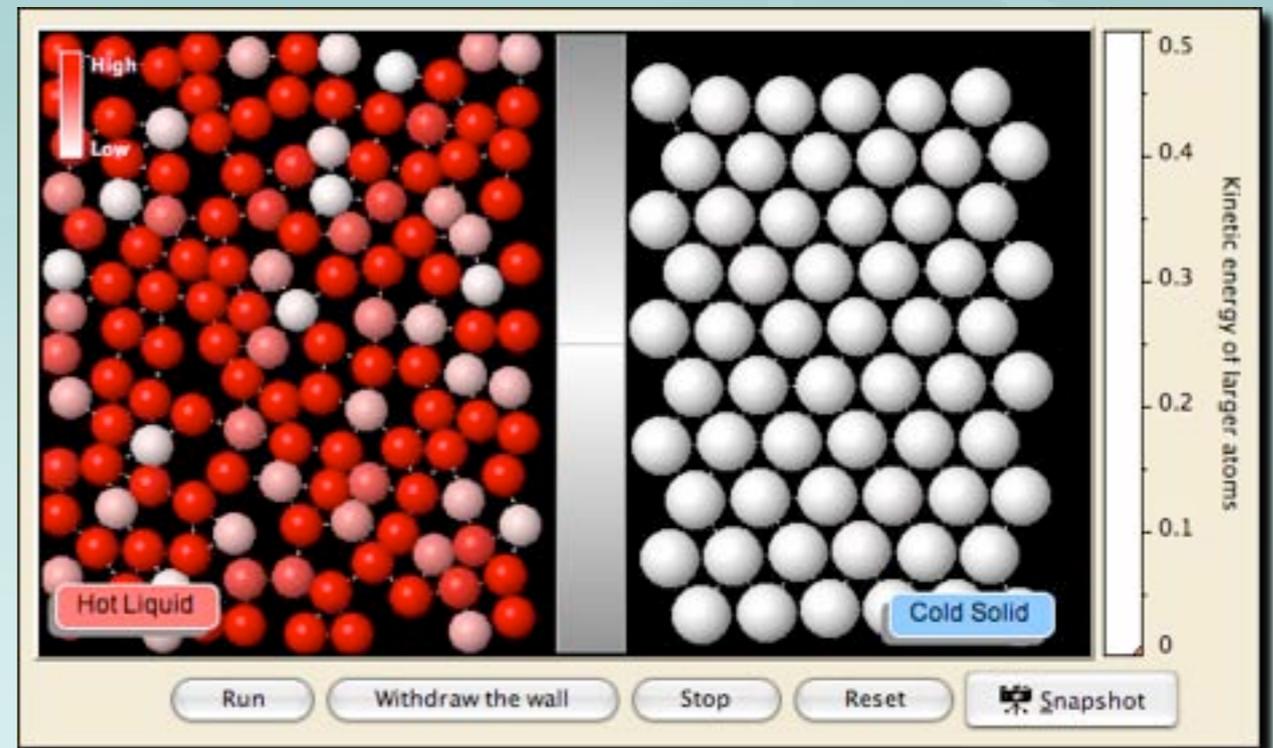
- Select a the initial molecule shape for the antibody by clicking on one of these images:



- Add charge to the antibody by using the charge tools $+$ and $-$ in the toolbar. To charge part of the antibody, select the appropriate charge tool and then click on the atoms you want to charge.
- Run the model, click on the green star, and "dock" the antigen to your antibody.
- Take a snapshot of your best creation.

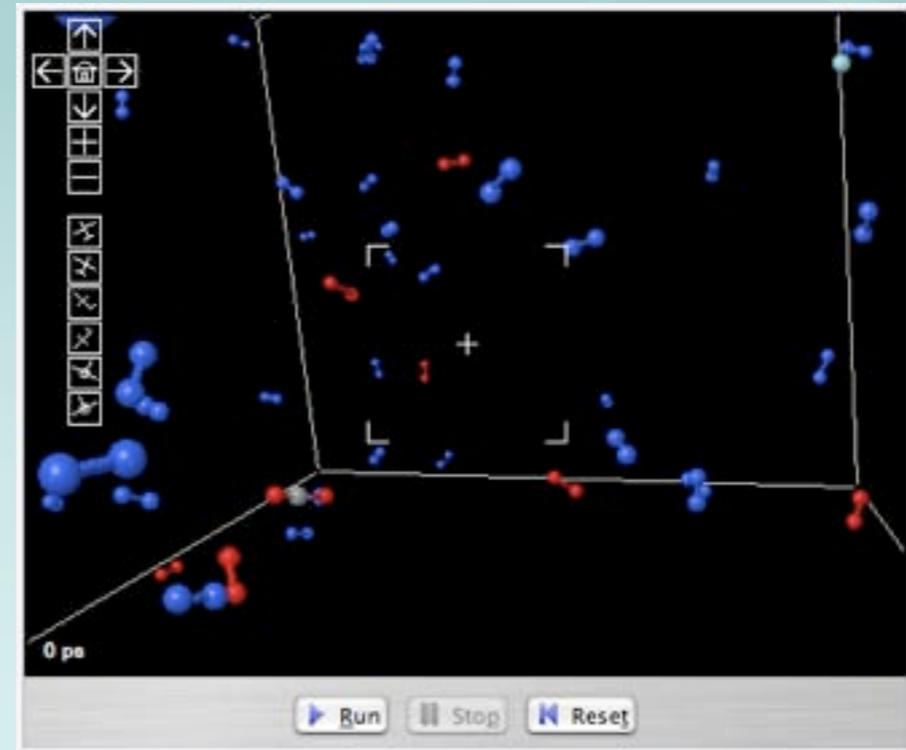
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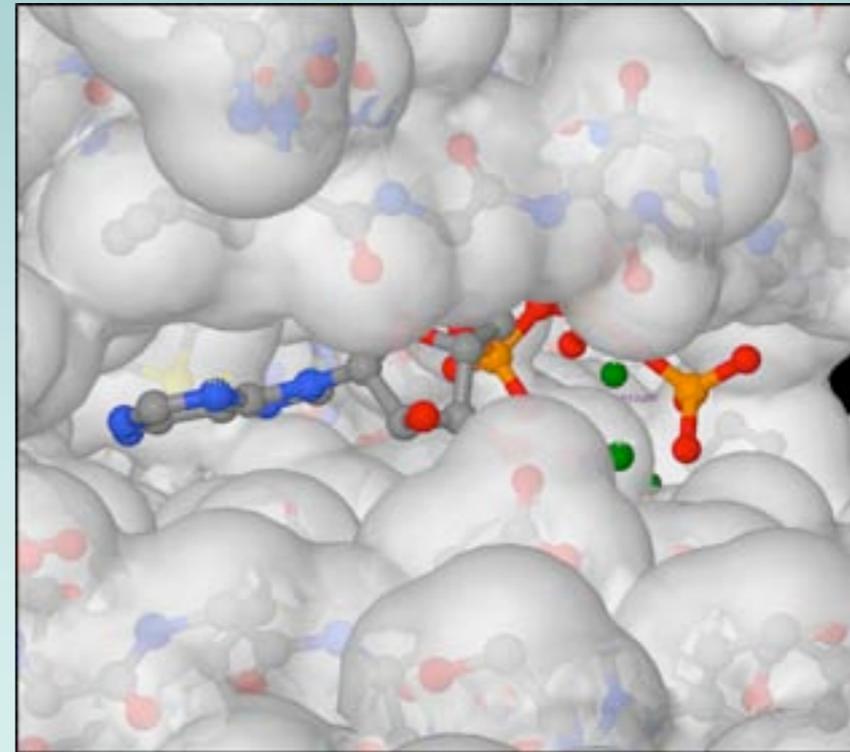
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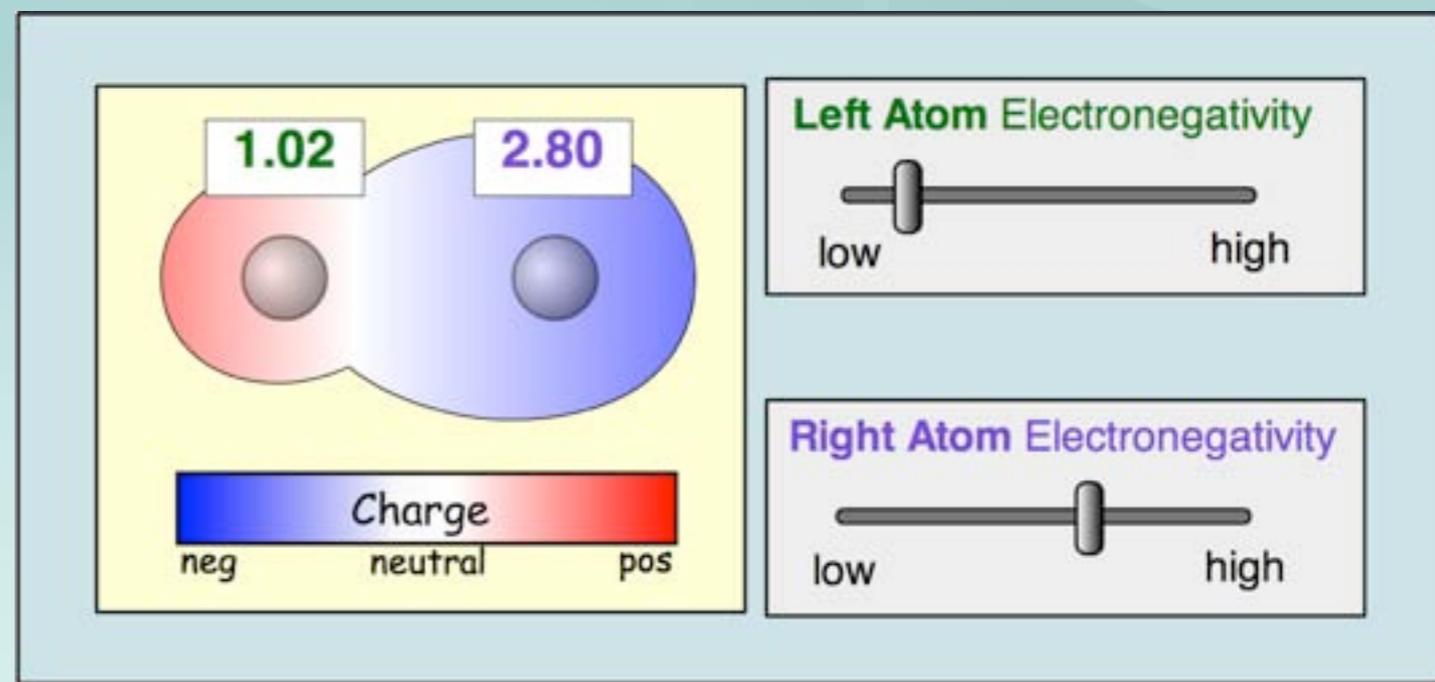
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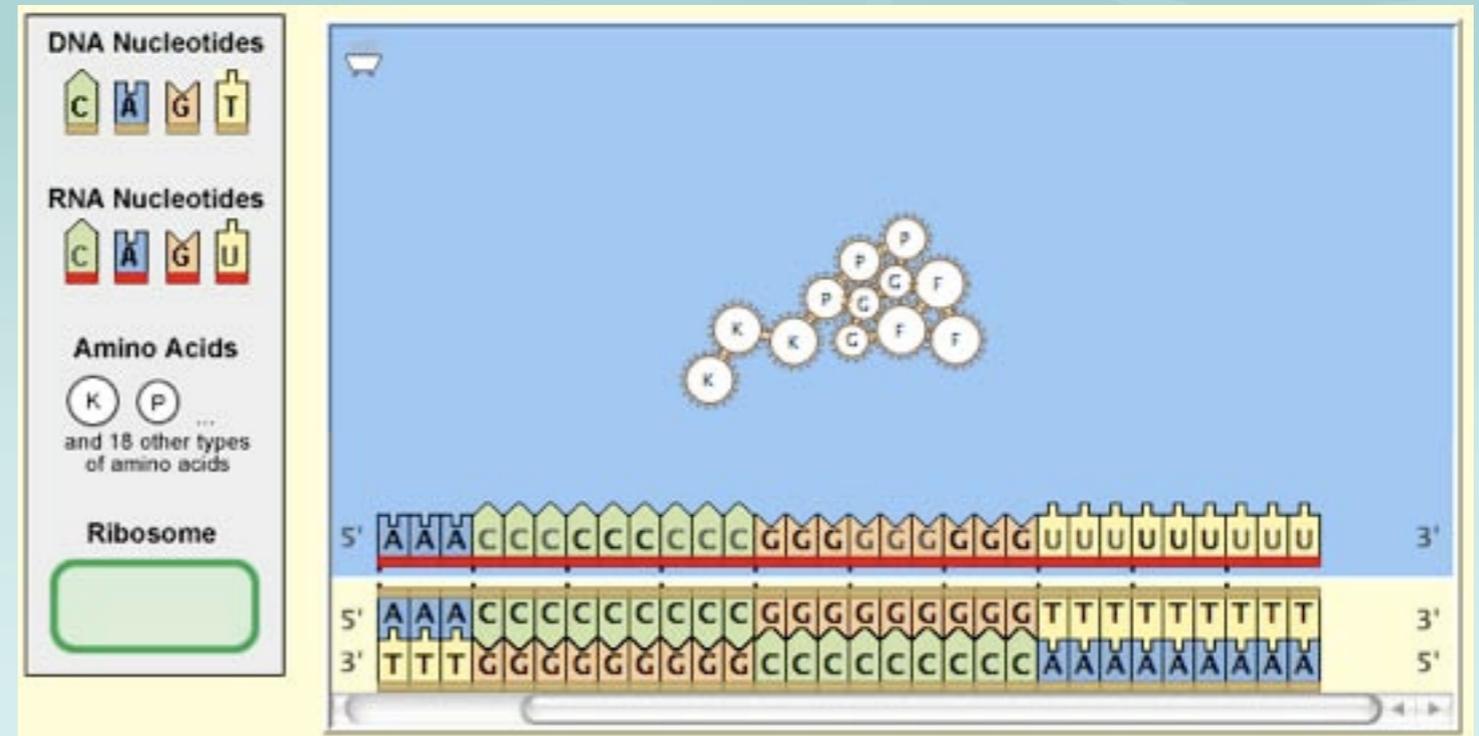
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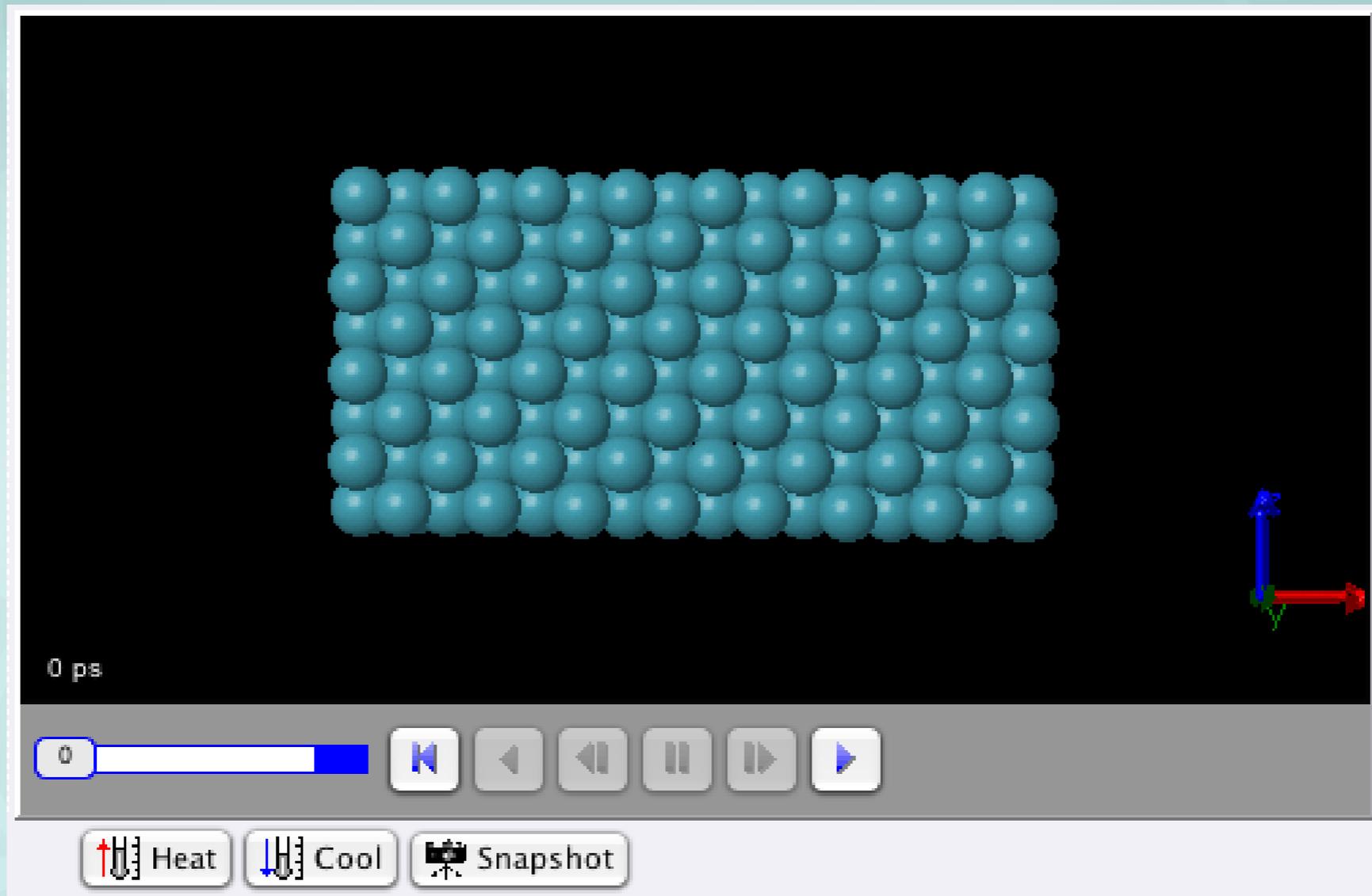


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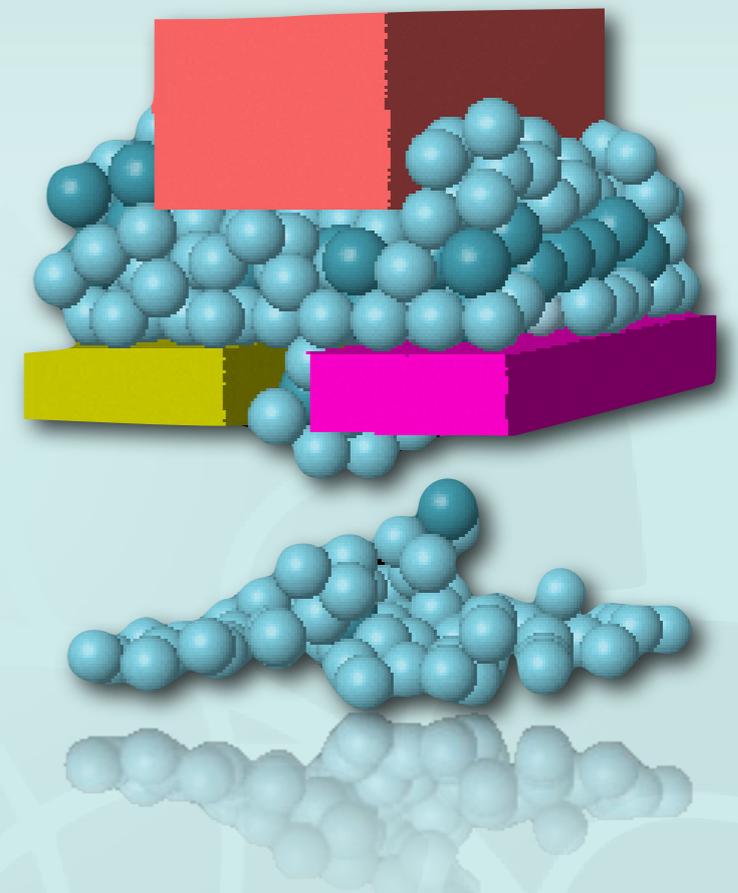
Dynamic Model of Phase Change



The image shows a dynamic model interface for phase change. The main window displays a 3D representation of a solid lattice of blue spheres. Below the window, there is a control panel with a time display showing "0 ps", a progress bar, and several control buttons: "Heat" (with a red up arrow), "Cool" (with a blue down arrow), and "Snapshot" (with a camera icon). A 3D coordinate system with red, green, and blue axes is visible in the bottom right corner of the simulation area.

Other Reasons to Use Models

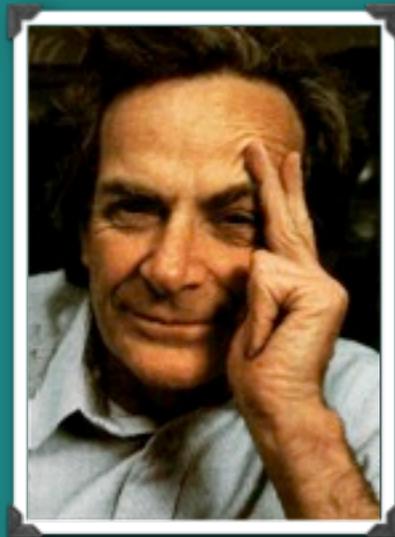
- Help to provide a concrete scaffold for new abstract concepts.
- Can be used in guided inquiry mode.
- Promotes reasoning and supporting ideas with evidence.





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	<u>Diffusion, Osmosis, and Active Transport</u>
	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 % [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%		
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TestA Damelin	They move fast. 38%	● 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 Ansv
TestB Damelin	They move fast. 100%	● Both the s...	Atom a will be slower.	● The pink a...	Kinetic energy is from the	● Some atoms...	● Be the sam... ● Be the sam... ● Denend	● Changing n...	The average goes up and down.	● They both ...	blah blah blah	blah bla

RI-ITEST DIY: http://ri-itest.diy.concord.org/reports/131/otml?group_id=be8ba548-d701-102b-a487-0...

Heat and Temperature (v3)

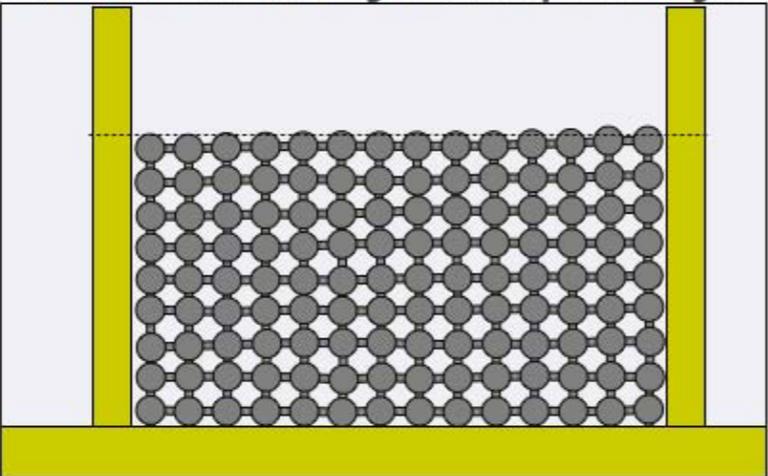
TestC Damelin
Teacher: Daniel Damelin
Class: chem1
Other Group Members:

1. Compare the motion of the air molecules at high and low temperatures.
They look the same to me.

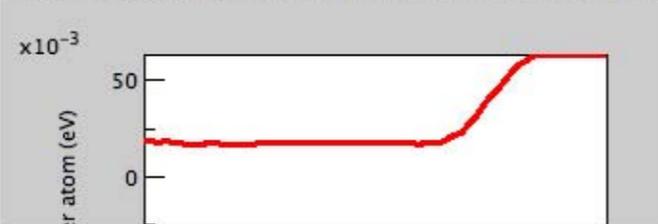
4. Which type of atom has the greater mass?

- The pink atoms.

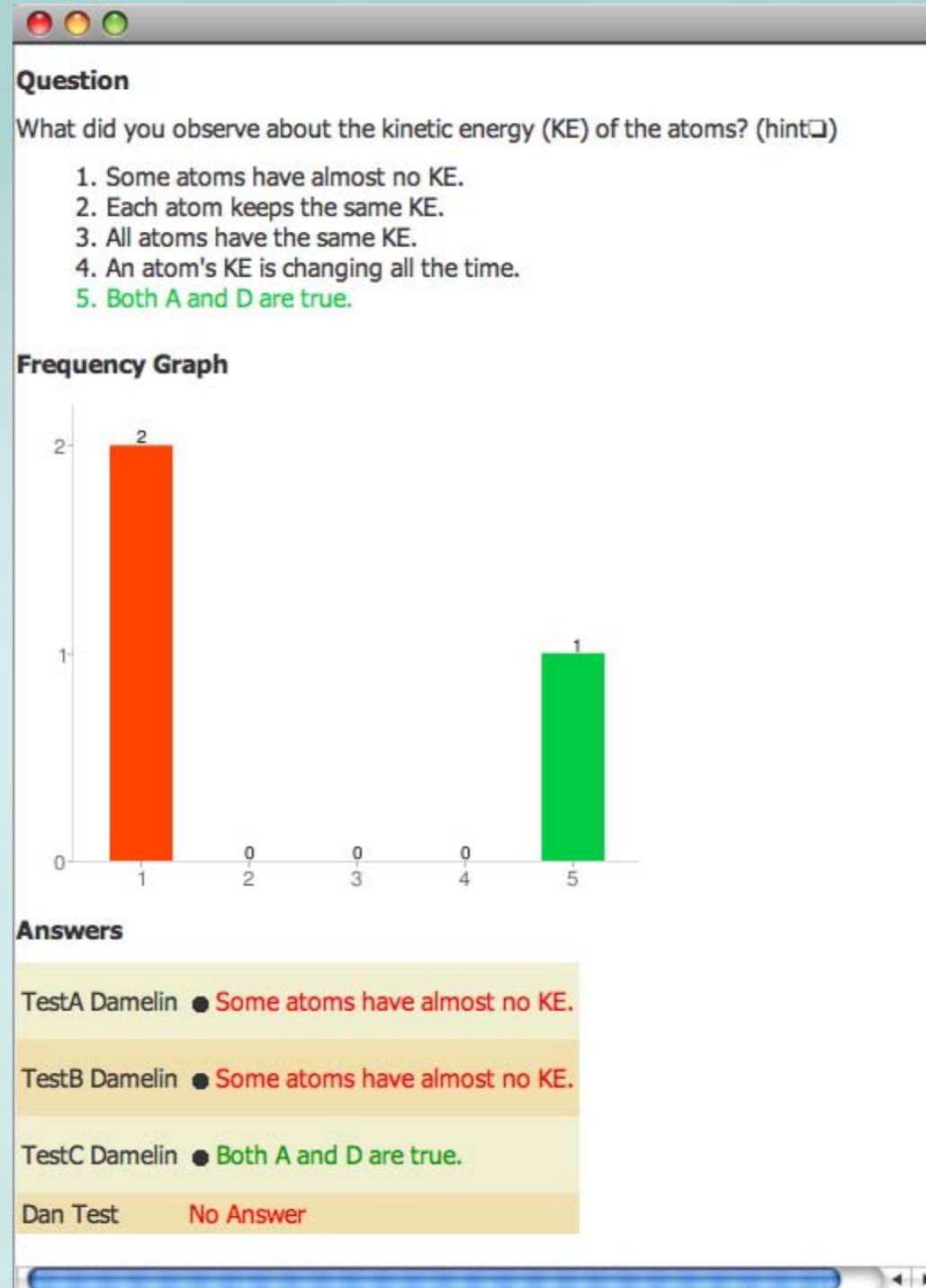
17. Take a snapshot of the model that shows thermal expansion, and then follow the instruction below to drag in the snapshot image.



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.

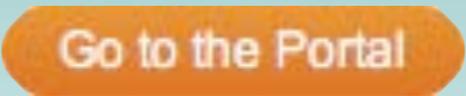


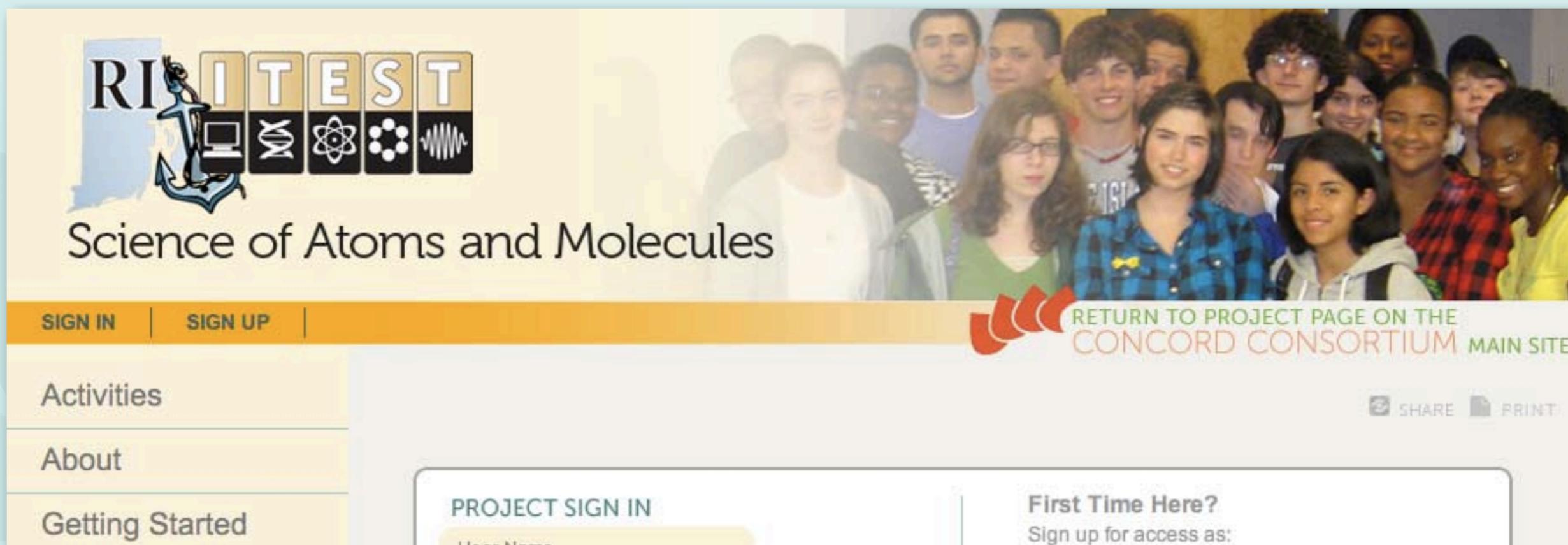
Student Data/Reporting





Previewing Models and Using the Portal

- Go to: <http://ri-itest.concord.org>
- Click on the  button.
- Click on the “Activities” link.
- Click the  button on an activity.



RI-ITEST
Science of Atoms and Molecules

SIGN IN | SIGN UP

RETURN TO PROJECT PAGE ON THE
CONCORD CONSORTIUM MAIN SITE

Activities

About

Getting Started

PROJECT SIGN IN

First Time Here?
Sign up for access as:

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)

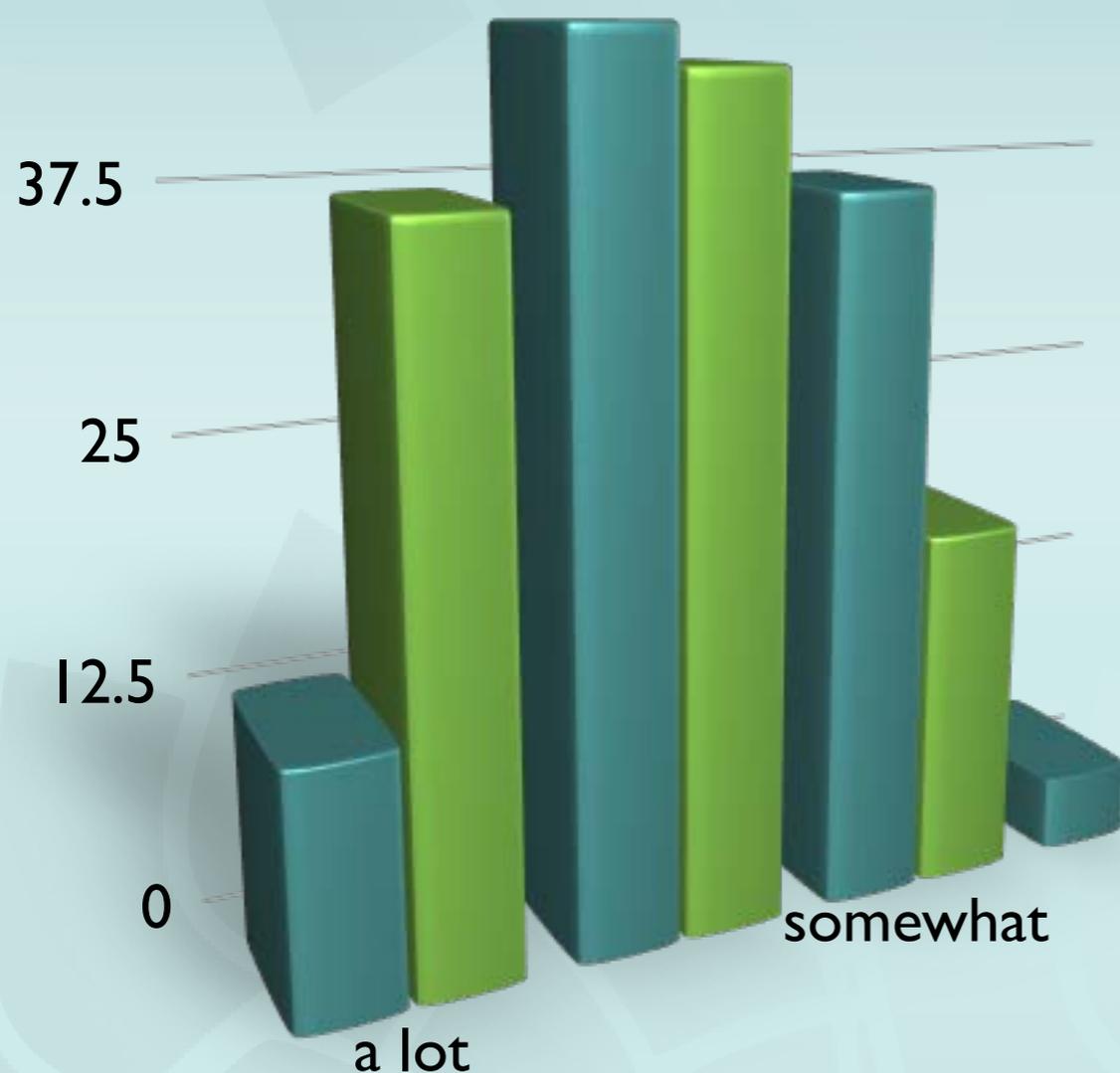




More PD in a Concentrated Area has Positive Outcomes

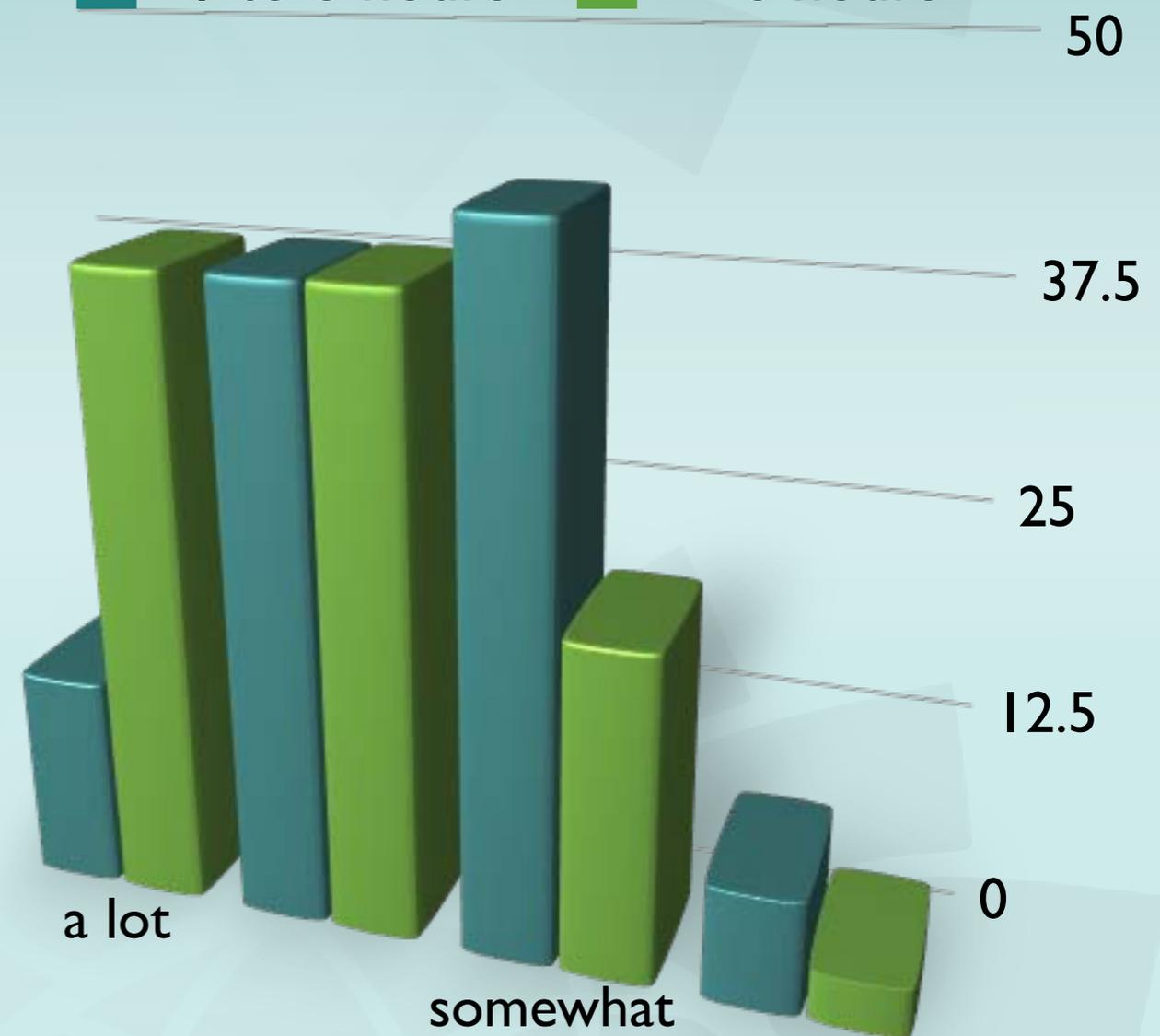
In Depth Study in Subject Area

■ 1 to 8 hours ■ > 8 hours



Technology Integration

■ 1 to 8 hours ■ > 8 hours



- 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			
	Spring	Sum	Fall	Spring	Sum	Fall	Spring	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

Weekend workshops					8	8		8		24
Online course					12	12		12		36
Summer workshop					30			30		60



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.

Do you 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**



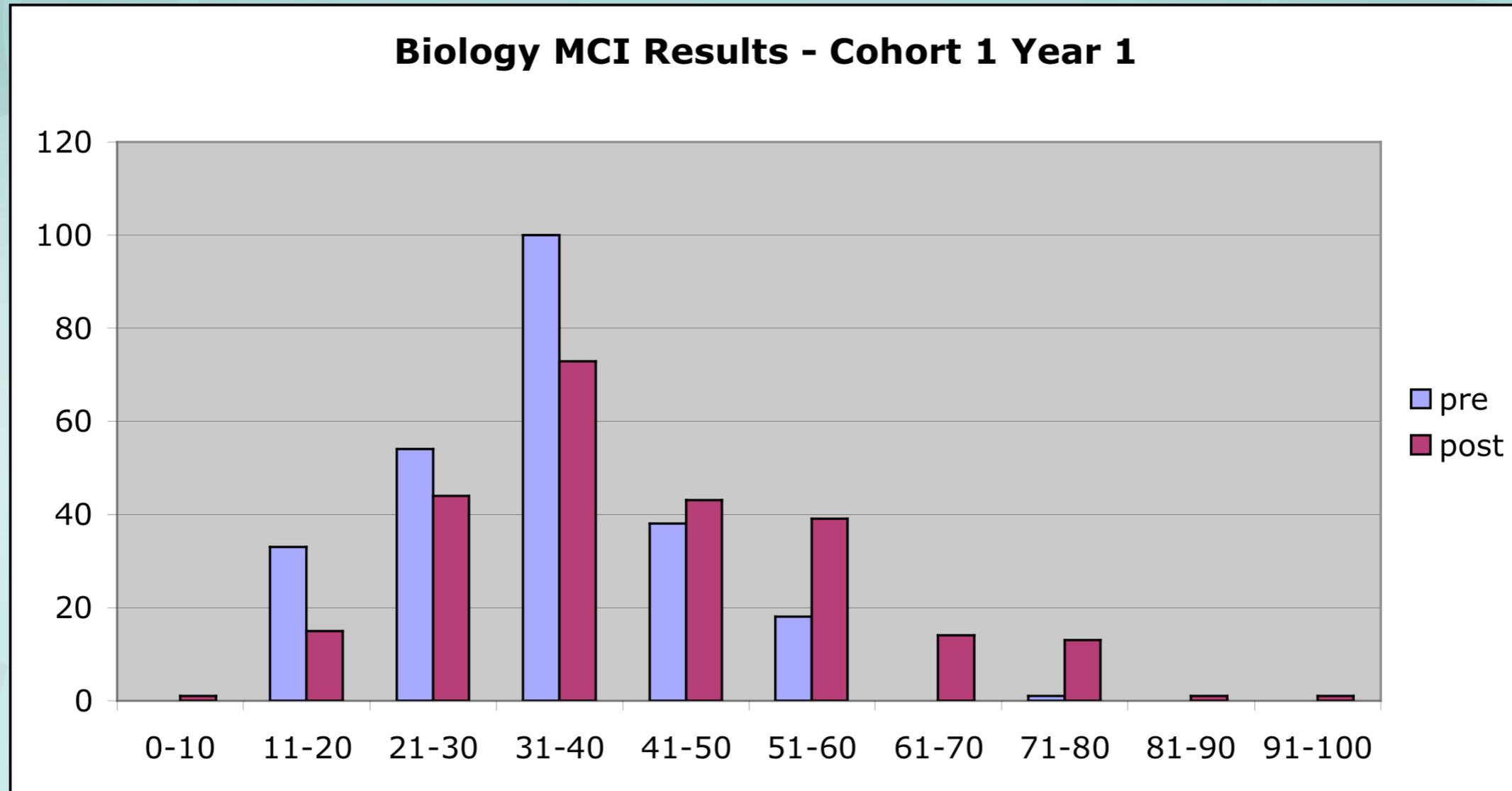
Student Impact

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

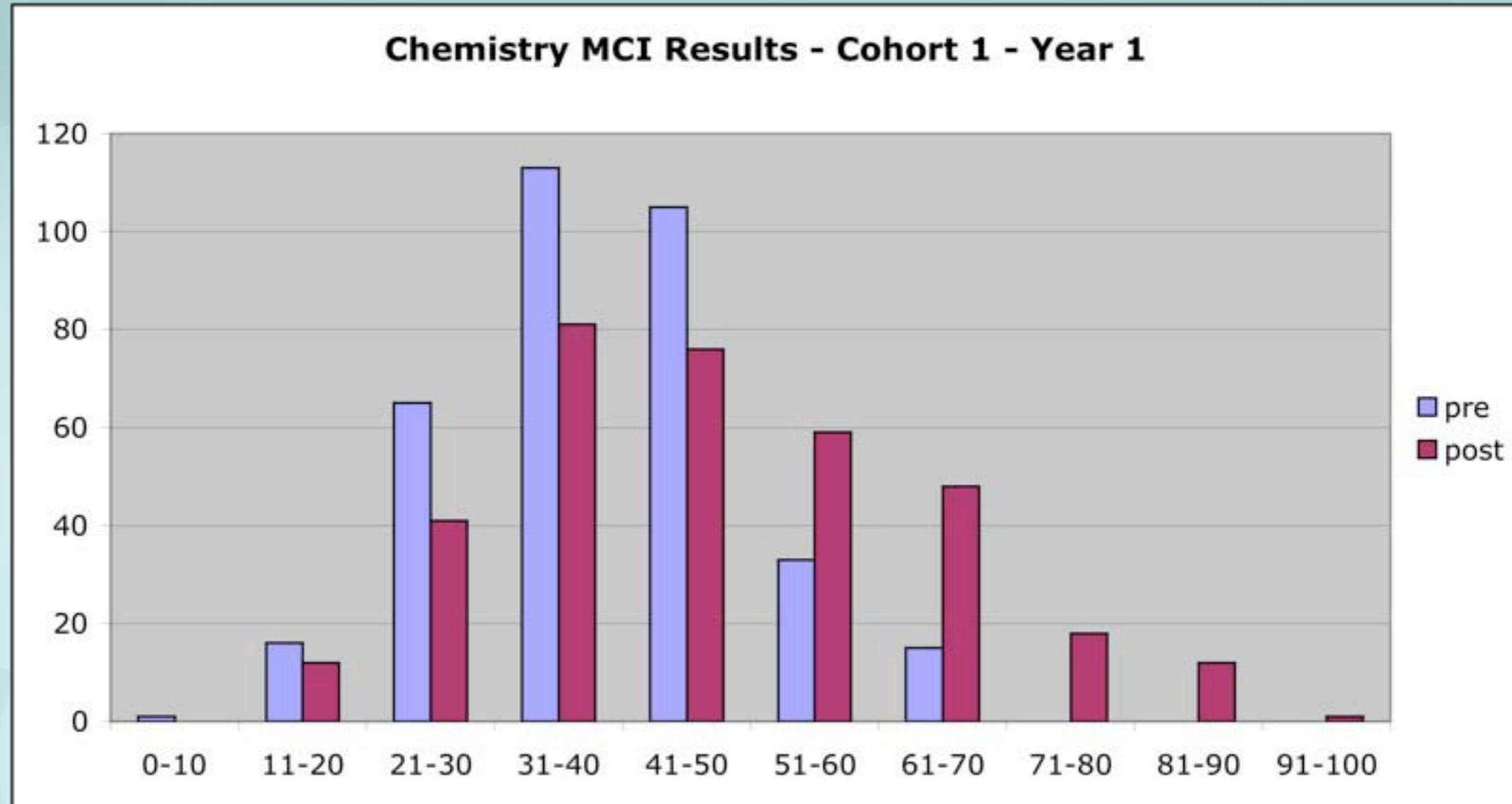
Cohort 1 - Bio



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

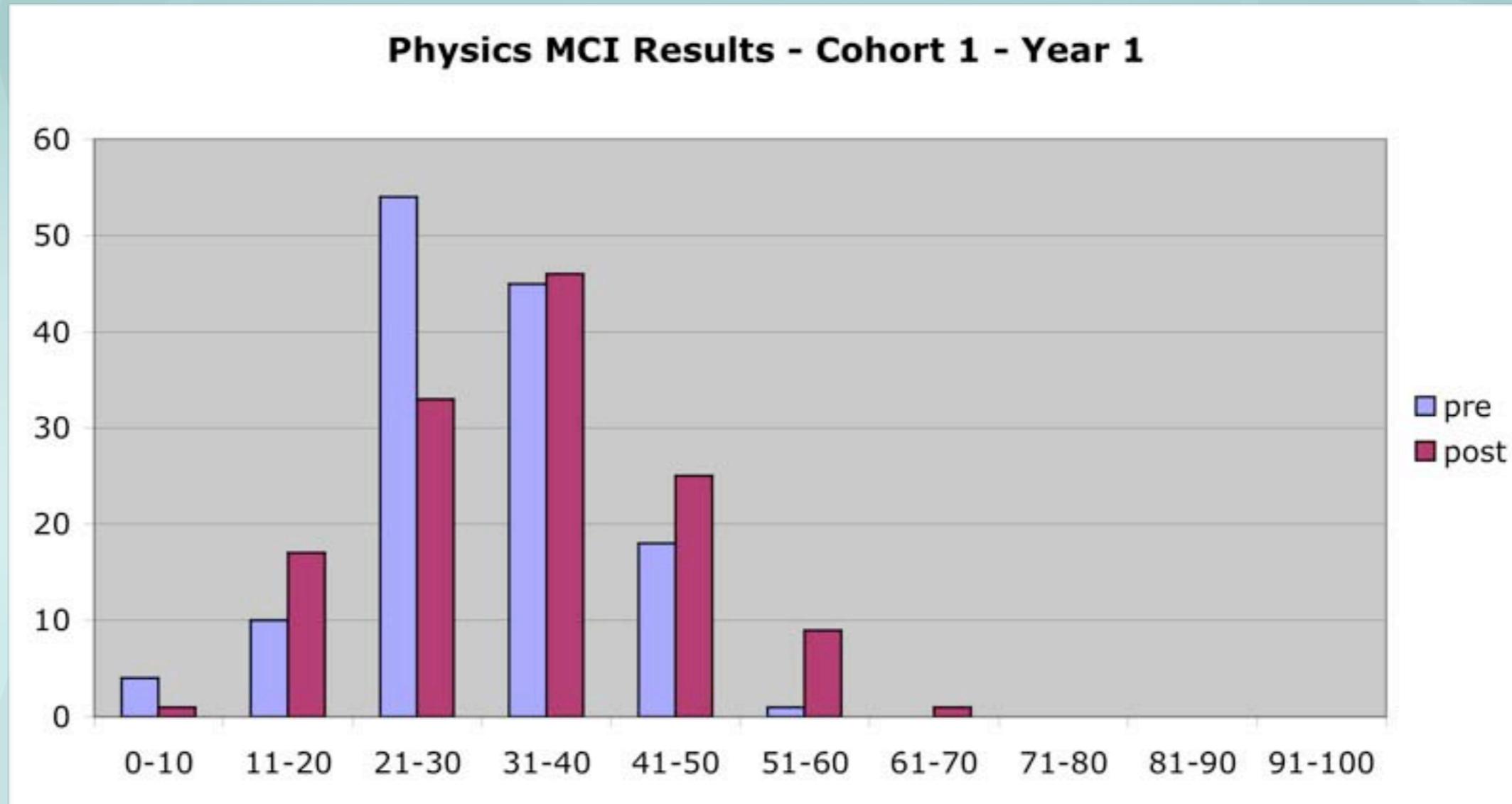
Cohort 1 - Chem



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

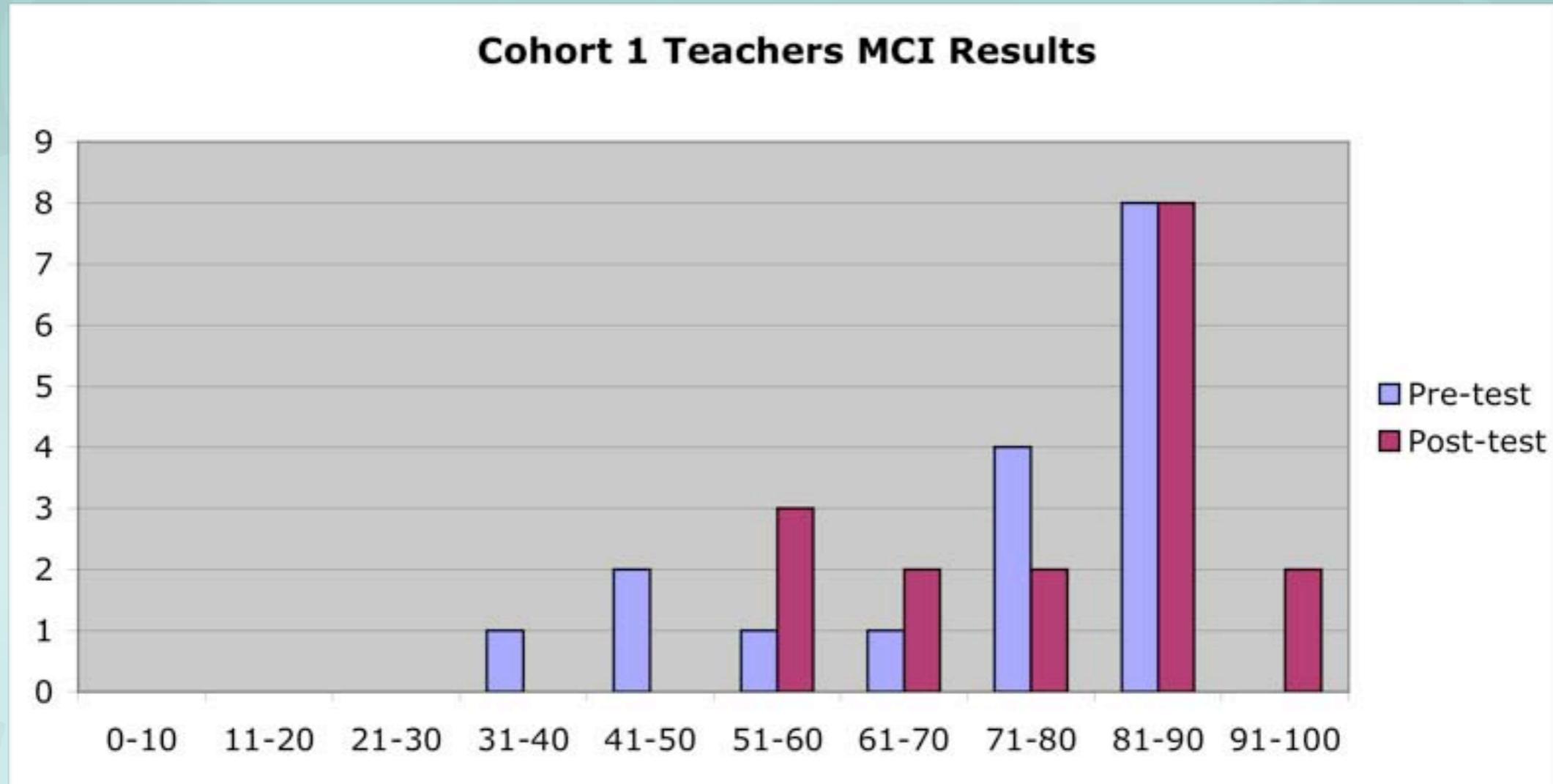
Cohort 1 - Physics



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

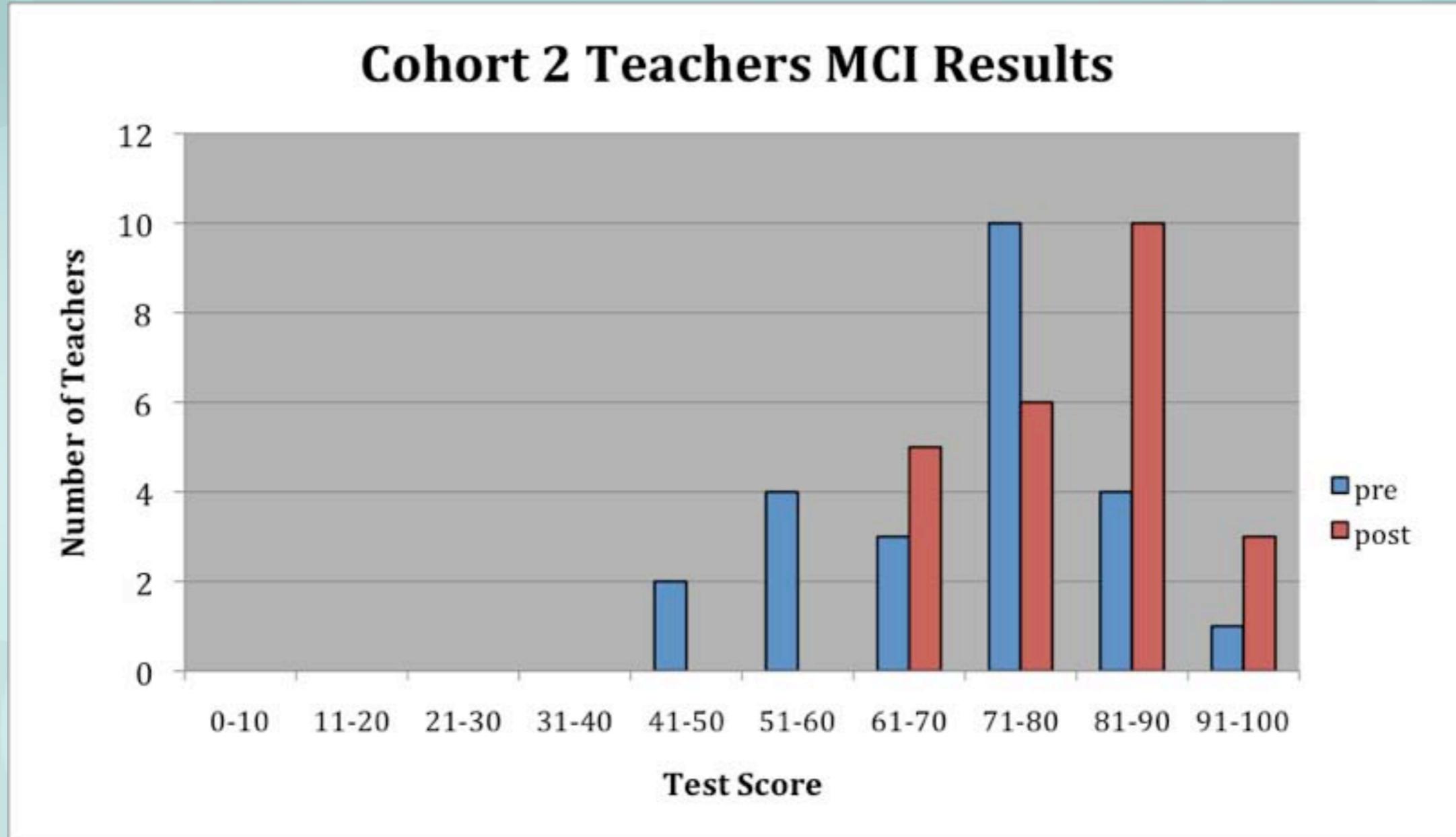
Cohort 1 - Teachers



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

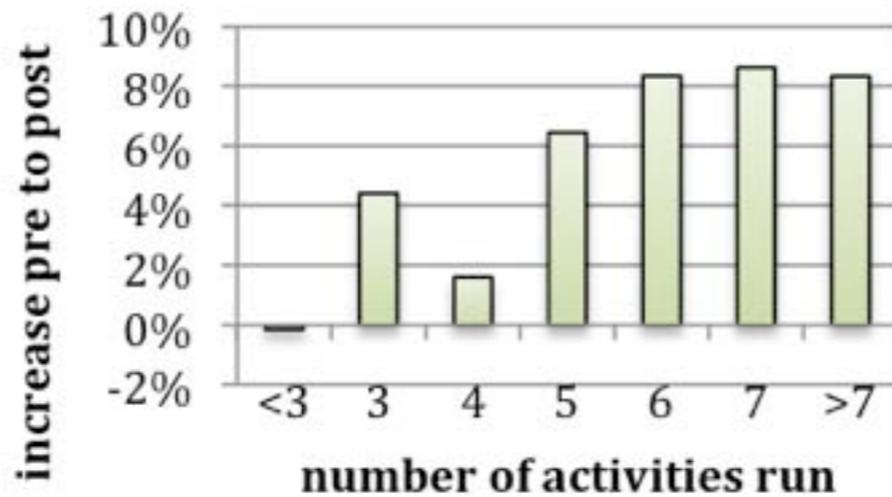
Cohort 2 - Teachers



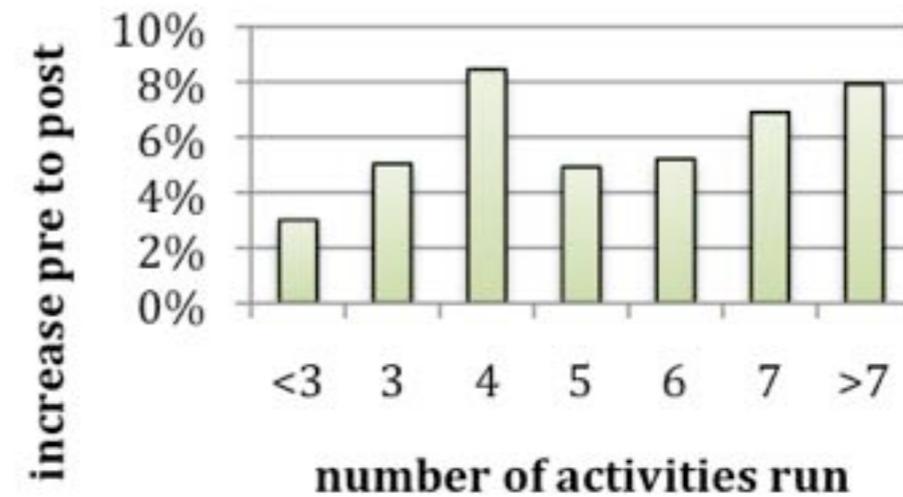
Cohort 2 Group	Pre-test mean	Post-test mean	n	p-value based on paired t-test	Cohen's d	Effect size
Teachers	72%	80%	24	5.3e-6	0.8	Large

Score increases related to number of SAM activities completed

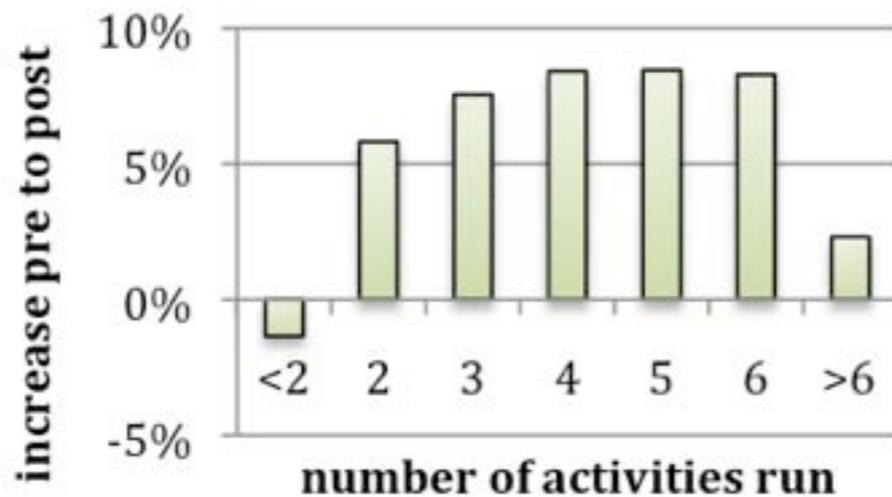
MCI score increase vs. number of activities run (Cohort 1 - chem)



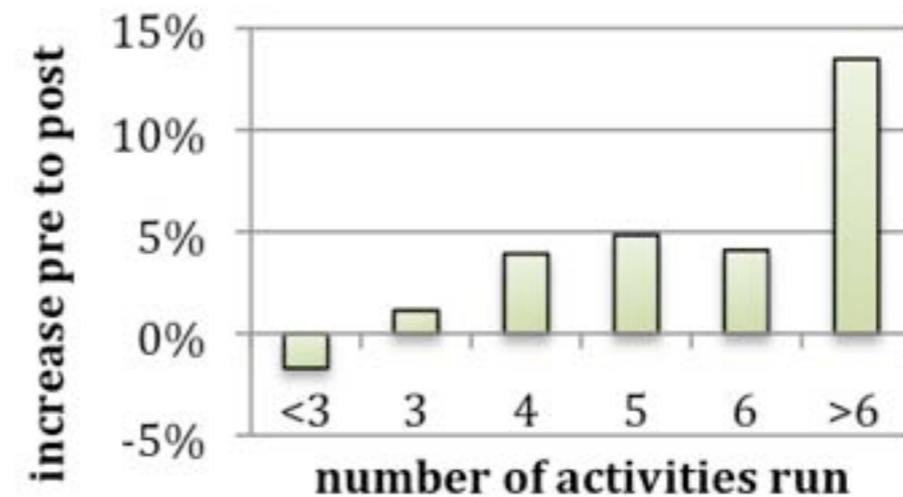
MCI score increase vs. number of activities run (Cohort 2 - chem)



MCI score increase vs. number of activities run (Chort 2 - physics)



MCI score increase vs. number of activities run (Cohort 2 - bio)



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.”



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