Chemistry for the Informed Citizen

AN INQUIRY-BASED CHEMISTRY CURRICULUM FOR NON-MAJORS

WHAT CAN (MOST) STUDENTS DO AFTER COMPLETING A TRADITIONAL INTRODUCTORY COURSE?

Readily solve quantitative, end-of-chapter problems (i.e., plug and chug).

0.100 mole of hydrogen gas occupies 600 mL at 25 ˚C and 4.08 atm. If the volume is held constant, what will be the pressure of the sample of gas at –5 ˚C?

(a) 4.54 atm (b) 3.67 atm (c) 6.00 atm (d) 2.98 atm

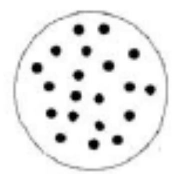
(e) 4.08 atm

Nakhleh, Mitchell (1993). J. Chem. Ed. 70(3) 190-192.

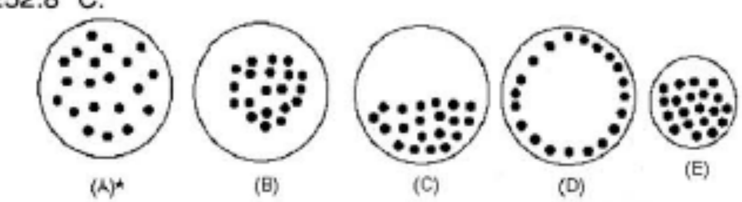
WHAT ARE (MANY) STUDENTS *NOT* ABLE TO DO?

Model underlying concepts with small particles.

The following diagram represents a cross-sectional area of a rigid sealed steel tank filled with hydrogen gas at 20 ˚C and 3 atm pressure. The dots represent the distribution of all the hydrogen molecules in the tank.



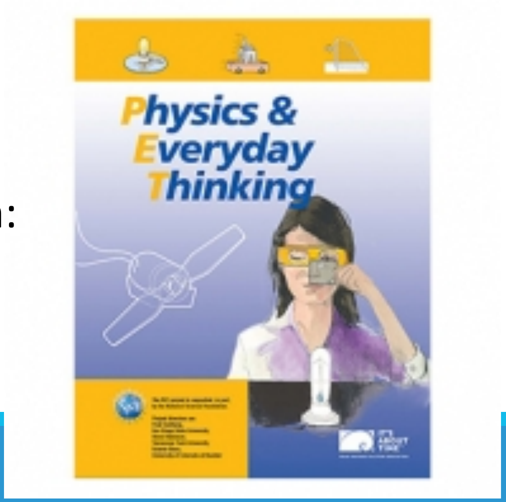
Which of the following diagrams illustrate the most probable distribution of molecules of hydrogen gas in the sealed steel tank if the temperature is lowered to –5 ˚C? The boiling point of hydrogen is –252.8 ˚C.

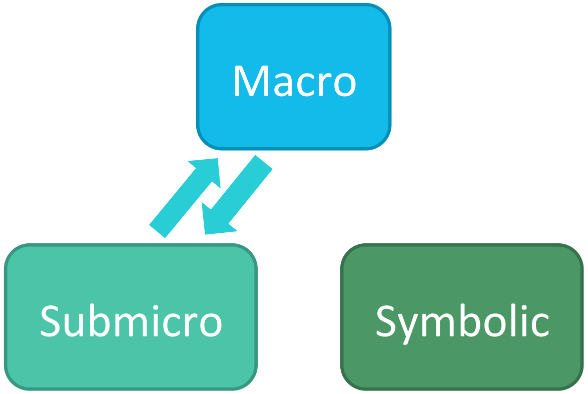


Chemistry for the Informed Citizen (CIC) Curriculum

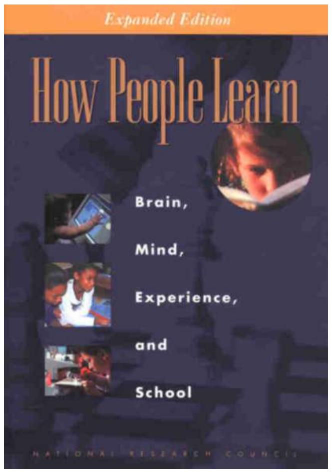
- Chemistry curriculum based on constructivist philosophy/ methodology for non-science majors
- Goal: Development of conceptual understanding of particulate nature of matter and chemical change
- Emphasis on building submicroscopic models to explain macroscopic phenomena

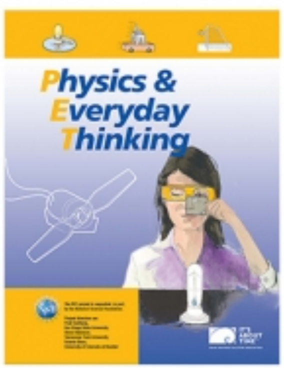
Model Curriculum:





Constructivist-based Elements of CIC curriculum





- **Key Finding #1:** Students come to classrooms with prior knowledge about how the world works.

  Initial ideas questions begin each activity

- **Key Finding #2:** Students must construct ideas in the context of a conceptual framework and organize knowledge effectively.

  Data collection/presentation with questions guiding interpretation and connection to small particles

- **Key Finding #3:** Metacognition allows students to take control and monitor their own learning.

  "Revisiting Initial Ideas" questions end each activity

Sample activity: Energy & bonding

Learning outcomes

1. Bond breaking is endothermic
2. Bond formation is exothermic

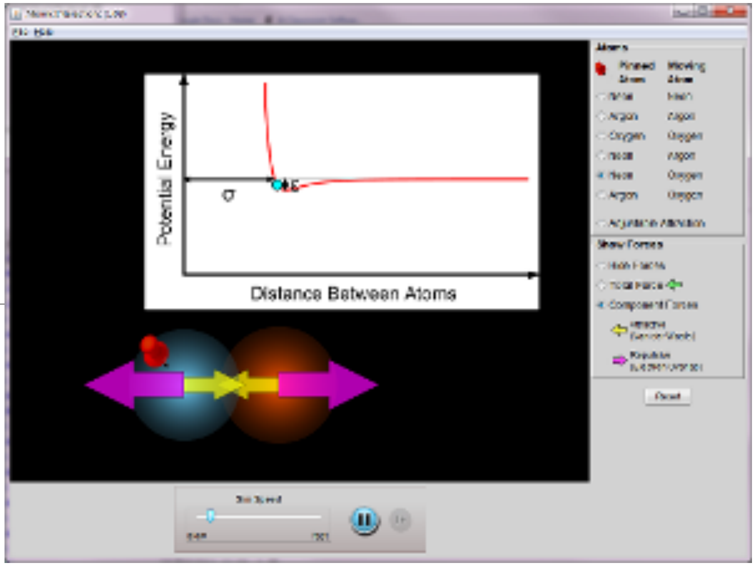
Design constraints

- Minimal math
- No quantum models
- Small particle description

Learning outcome #1:
Defining a bond

PHET Atomic interactions simulator:

http://phet.colorado.edu/en/simulation/atomic-interactions



What about the atom's motion serves as evidence that it is attracted to the other atom? What about its motion serves as evidence that it is repelled by the other atom?

How does the attractive force change as the atoms get closer? *increases / decreases / stays the same.* How does the repulsive force change as the atoms get closer? *increases / decreases / stays the same.*

Identify the distance at which the attractive and repulsive forces are the same magnitude (we call this situation "balanced forces" – the "pull" is the same strength as the "push.") Draw an asterisk at that point on the potential energy curve.

A source of student misconceptions about energy & bonds

Confusing changes in energy needed to bring about a change in bonding with changes in energy as a result of changes in bonding

Case	Question	Manipulated (independent) variable	Responding (dependent) variable
Bond-manipulated	What happens to the energy in the system as a result of bond formation or breaking?	Bonding	Energy changes
Energy-manipulated	What happens to the bonding situation in the system as a result of energy input or output?	Energy changes	Bonding

Learning outcomes #2&3: Bond breaking is endothermic, bond formation is exothermic

1. Empirical evidence
2. Small particle modeling with simulator

Challenge: What are systems that illustrate temp changes due <u>solely</u> to spontaneous bond breaking or formation (not both)?

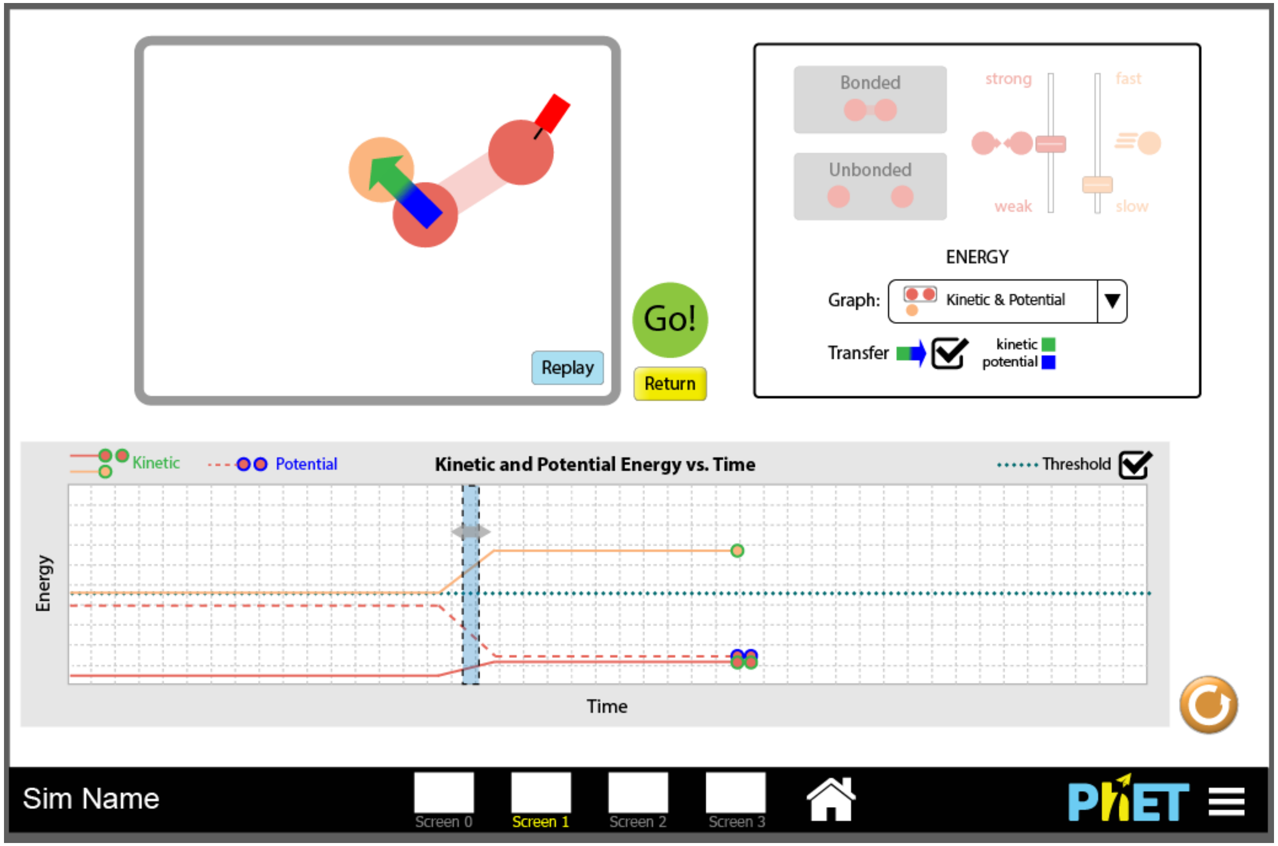
Learning outcomes #2&3: Bond breaking is endothermic, bond formation is exothermic

Small particle modeling:

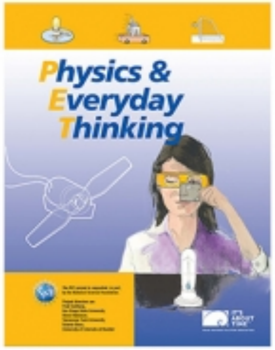
http://besocratic.colorado.edu/CLUE-Chemistry/activities/LondonDispersionForce/1.2-interactions-2.html

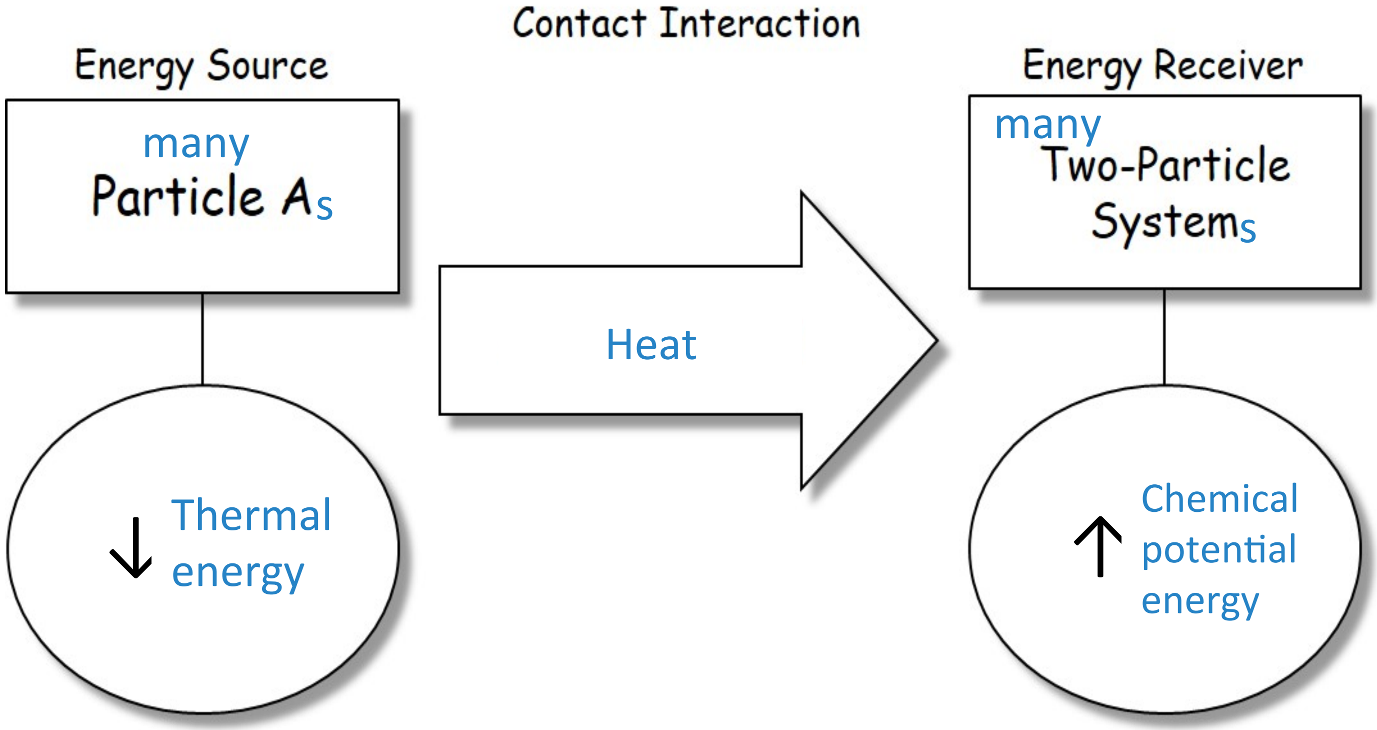
http://besocratic.colorado.edu/CLUE-Chemistry/activities/LondonDispersionForce/1.2-interactions-1.html

A tangent. . . (my sabbatical project)

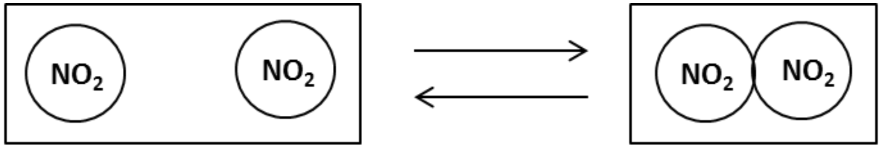


Energy Diagrams





The energy manipulated case



2 molecules of nitrogen dioxide (NO_2)
brown color

One molecule of nitrogen tetroxide (N_2O_4)
colorless

More NO_2 in NO_2/ N_2O_4 mixture

More N_2O_4 in NO_2/ N_2O_4 mixture

Students' beginning ideas: SCED 204

Heat is given off when hydrogen burns in air according to the equation

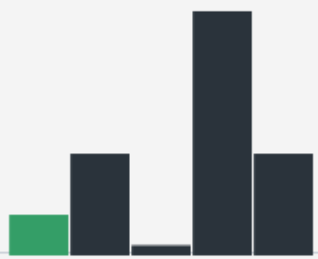
$2H_2 + O_2 \text{ --> } 2H_2O$

Which of the following is responsible for the heat?

7%

Correct answer

7% of your students correctly answered this question.



-0.00 Discrimination Index

7% A. Breaking hydrogen bonds gives off energy.

20% B. Breaking oxygen bonds gives off energy.

0% C. Forming hydrogen-oxygen bonds gives off energy. Correct

53% D. Both (A) and (B) are responsible.

20% E. (A), (B), and (C) are responsible.

Students’ final ideas: SCED 204

10. Heat is given off when hydrogen burns in air according to the equation

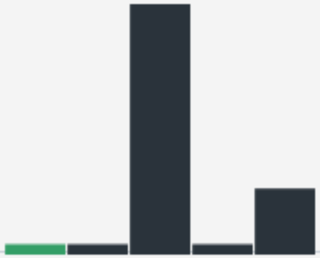
$2H_2 + O_2 \rightarrow 2H_2O$

Which of the following is responsible for the heat?

0%

Correct answer

0% of your students correctly answered this question.



-0.00 Discrimination Index

- 0% a. Breaking hydrogen bonds gives off energy.
- 0% b. Breaking oxygen bonds gives off energy.
- 82% c. Forming hydrogen-oxygen bonds gives off energy. Correct
- 0% Both (a) and (b) are responsible.
- 18% (a), (b), and (c) are responsible.

A balancing act. . .

100% Accuracy

Detail

Completely turning over misconceptions about bonding and energy

VS.

Accessibility of ideas to non-science major's audience

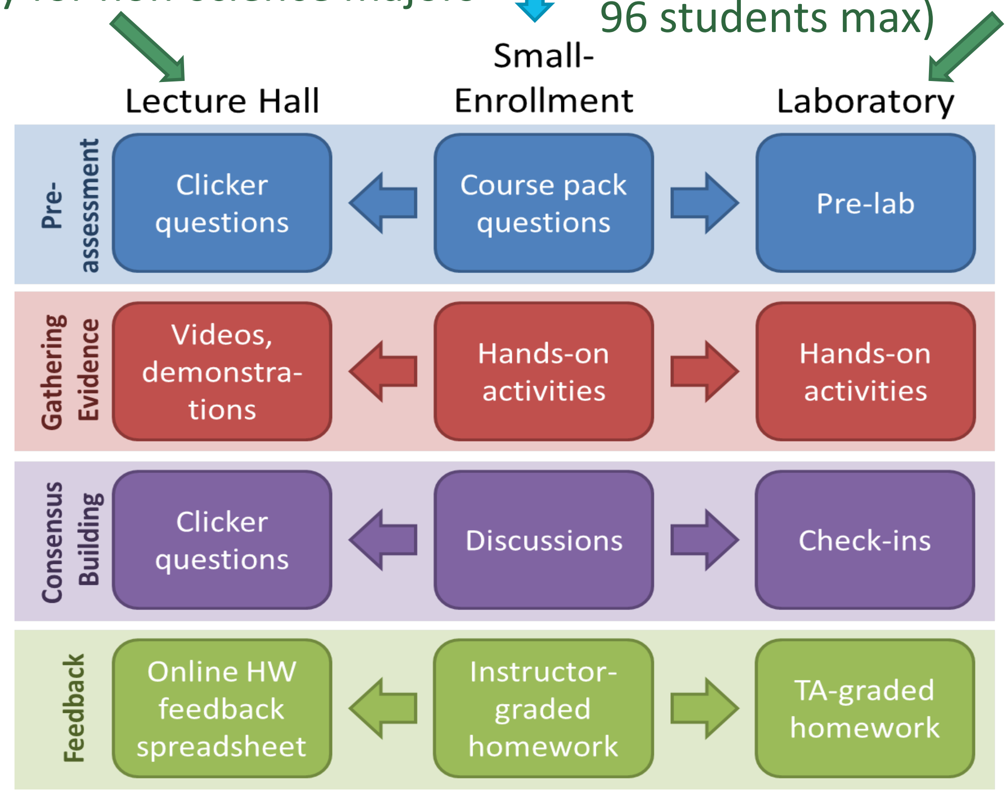
Simplicity/unifying themes

Addressing other misconceptions/difficulties that might be more applicable to everyday life (?) (e.g. intermolecular forces)

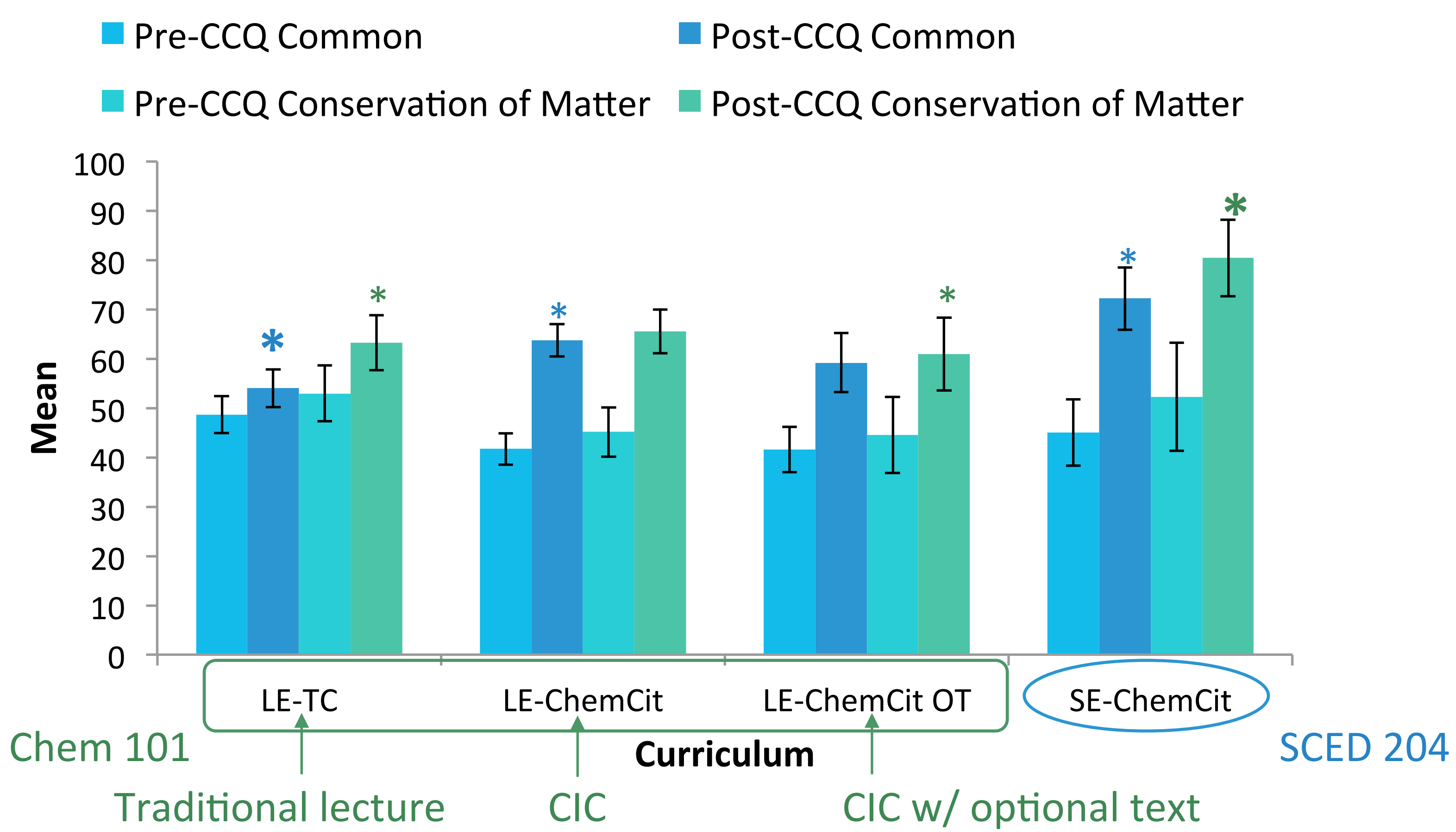
Adaptation of CIC to two different contexts

SCED 204: Chemistry for preservice elementary teachers (3x2 hrs/week; 24 students max)

Chem 101: Chemistry for non-science majors (3x1 hr/wk lecture; 1x3 hr/week lab, 96 students max)



Scaling up


Pre-CCQ Common
Post-CCQ Common
Pre-CCQ Conservation of Matter
Post-CCQ Conservation of Matter
Mean
100
90
80
70
60
50
40
30
20
10
0
LE-TC
LE-ChemCit
LE-ChemCit OT
SE-ChemCit
Curriculum
Chem 101
SCED 204
Traditional lecture
CIC
CIC w/ optional text

Acknowledgements

Research assistants

Matt Lockett

Siri Wuotila

Kayla Anzalone

Jared Ogle

Greg Pennington

Curriculum development team

Andrew Boudreaux, WWU, Physics

Ben Fackler-Adams, Skagit Valley College, Earth, Physical Science

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National Science Foundation DUE-0737551