Formative Assessment to Improve Student Understanding in Chemistry

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Chemistry Facets

Goals

The Chemistry Facets project brings together experts in assessment, science education, chemistry teaching, and chemistry content to develop a web-based system to support teachers' use of formative assessment to promote conceptual change in chemistry.

The goals of the project are to:

- Identify and develop clusters of facets (student ideas and understandings) related to key high school chemistry concepts
- Develop assessment items that diagnose facets within each cluster
- Enhance the existing web-based Diagnoser assessment system for administering items, reporting results, and providing teacher resources for interpreting and using the assessments
- Develop teacher professional development and resource materials to support their use of facet-based approaches
- Examine whether student learning and motivation to learn in chemistry improve for students in chemistry classes that incorporate a facet-based assessment system

Anticipated Products

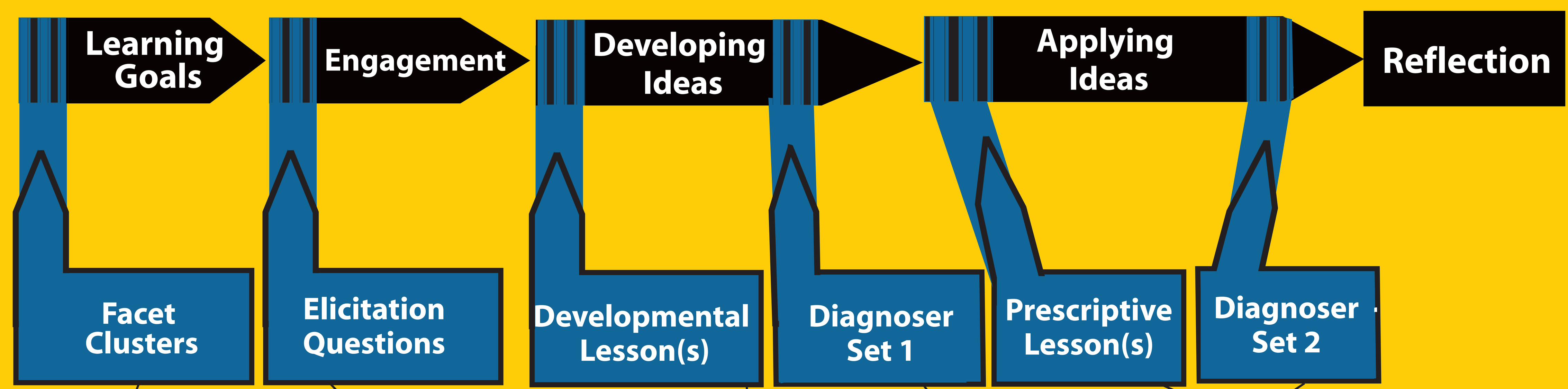
- 6 facet clusters on the Atomic Structure of Matter
- 4 facet clusters on Changes in Matter
- Up to 20 validated items per cluster
- Teacher resources including elicitation questions and classroom activities related to each cluster, and a framework for professional development
- A web-based Diagnoser for chemistry, including student assessments and teacher resource materials (www.diagnoser.com)

Project Evaluation

The evaluation plan consists of three components: (1) a small-scale experimental study to examine the efficacy of the use of Diagnoser with Washington and California high school chemistry students and teachers, (2) an Advisory Board to monitor and assess the work, and (3) an external evaluator to assess the facet and item development, as well as factors affecting implementation. Multiple forms of evidence will be used to demonstrate achievement of the project goals. We will examine the cognitive, instructional, and empirical validity of the formative assessment systems. Cognitive interviews will provide information about whether Diagnoser question sets are eliciting intended facets of understanding and providing appropriate feedback to students. A small-scale quasi-experimental study will provide insights into the extent to which this approach benefits student understanding of chemistry concepts.

Integrating the Diagnoser Tools With Curriculum

Planning Your Curriculum/Unit Cycle

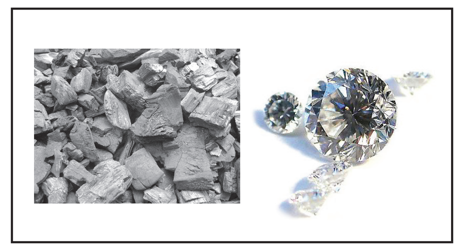


Diagnoser Instructional Tools

Facet Clusters	Description
1.1. Atoms	All matter is made up of atoms, which are too small to be seen even with a powerful microscope. Atoms cannot be created or destroyed by ordinary chemical or physical means.
1.2. Model of an Atom	The student correctly uses a model for the atom to account for the structure of matter.
1.3. Elements	There are only about 100 different kinds of elements, each of which is composed of a single kind of atom. In atoms of the same element there is the same number of protons; the number of neutrons or electrons may be different.
1.4. Electrons	Two competing forces on an electron are its attraction to the nucleus and its repulsion from other electrons. Electrons reside outside the nucleus in defined spaces. We can only identify the spaces where electrons have a high probability of being found.
1.5 Precursor to Bonding	Atoms join together in specific ratios and arrangements to form molecules. Observable properties of compounds can be different than the observable properties of their elements.
1.6. Ways Atoms are Held Together (Bonding)	Atoms form bonds by sharing, losing, or gaining electrons to result in a full set of valence electrons. Different types of bonding can result in differences in physical properties of compounds.
2.1. Describing Changes	Macroscopic changes are due to different interactions between the small particles of matter, and matter neither ceases to exist nor comes into existence during those changes.
2.2. Changes Where the Substance Stays the Same	During physical changes (e.g., dissolving and phase changes), particles do not change in size, shape, mass, and composition. Energy is absorbed or released during physical changes.
2.3. Changes that Result in New Substances	During chemical changes, new substances are formed. Students can account for all the atoms and describe the bonds that must be broken and/or formed through representations.
2.4. Energy and Rates of Chemical Reactions	Chemical reactions exchange energy based on the stability of reactants and products. Chemical reaction rates can be altered, and equilibrium occurs when the forward and reverse reaction rates are equal.

Elicitation Questions

1. The hunk of charcoal and the diamond shown in the pictures below both are made of carbon atoms. Imagine you could see one carbon atom from the coal and one carbon atom from the diamond. How would they be the same? How would they be different?



2. Describe what makes atoms stick together to form a molecule. What role do the subatomic particles have in this interaction?
3. When you bake a cake in the oven, why does it go from liquid batter to a solid cake? What happens to the particles?

Model of an Atom Developmental Lesson

I. Introduction
Models are a simple way of thinking of something that is con… or difficult to observe directly. Models are limited so we must… not to draw conclusions beyond the reach of the model. For i… if we are using a billiard ball model of the atom, it may help u… motion but the color and size are not correct. A good model… us to solve the problem at hand AND will suggest other solut… to problem we had not expected to solve. Today we will atte… model the size and location of parts of the atom.
II. Materials
Rice, Confetti, Juice cans, balls, yarn/string/Play-Doh
III. Procedure
A. Look at the picture of the atom that you drew in the Elicita… Question.
B. Is your drawing to scale? How would you change it thinkin… scale model?
C. We are going to experiment to determine which model of the atom best explains the data we collect by rolling a particle at the atom and using a screen to detect where the particle goes after we roll it.
D. Using the first data chart provided, draw in your model of the atom from your picture.
E. Where do you predict the particle will go if it is rolled at your model? Will it bounce off, Will it go past? Will it come back?
F. Now the teacher will group you based on your model types and hav… you build your model.
G. Build your model using the materials provided.
H. How big does the detector screen need to be?
I. Without looking, roll a particle (about the size of one of the nuclear particles) at it, and record where the particle went in the second data chart provided.

Model of an Atom Diagnoser Set

1. Imagine that you have a very thin sheet of gold that is only one atom thick. A positively charged particle that is much smaller than a single gold atom is shot at the gold sheet. Which is the most likely outcome for the particle?
   a. Pass right through [paired with 2a]
   b. Bounce straight back [paired 2c]
   c. Get deflected back at some angle [paired 2c]
   d. Get stuck in the gold sheet [paired 2b]
   e. Make a hole in the gold sheet [paired 2a]
   f. Knock out part or all of a gold atom [paired 2a]

2a. [Paired with responses from Q1a, e and f.] Which of the following statements best matches your reasoning on the previous question?
   a. The gold atoms are solid, but there is space between each atom for the particle to pass though. [50]
   b. The gold atoms are mostly empty space, so the particle can go through the atoms. [01]
   c. The particle will move the atoms aside to pass through. [50]
   d. Since the particle is charged, it will be strong enough to move a gold atom. [TBD]
   e. Other [send to text question 2other to explain]

2b. [Paired with response from Q1d.] Which of the following statements best matches your reasoning on the previous question?
   a. Since the particle is small it won't have the strength to make it through. [50]
   b. The particle gets stuck because it is too attracted to the electrons. [TBD]
   c. Other [send to text question 2other to explain]

2c. [Paired with responses from Q1b and c.] Which of the following statements best matches your reasoning on the previous question?
   a. The gold sheet is solid, so there is no space for the particle to get through. [50]
   b. The atoms are solid balls, so the particle bounces off. [50]
   c. The nucleus takes up a large part of the atom, so the particle is repelled by it. [72]
   d. Even though the nucleus takes up a small part of the atom, a few of the particles will be repelled by it. [02]
   e. Other [Send to 2other]

2other. Explain your reasoning for the prediction you made in question 1.

Elements Prescriptive Activity for Facet 70

The student thinks that the physical properties of a substance (color, density, hardness, etc...) are also properties of the individual atoms that make up that substance.

Most common conditions where Facet 70 occurs:

Students attribute the physical properties of a substance to the molecules or atoms of that substance. Students often carry this notion unless they are explicitly aspect to confront the notion of physical properties of molecules and atoms.

Activity to address Facet 70:

Substances have physical properties like boiling point, freezing point, color, concentration, density, electric charge, flow rate, solubility, specific heat, viscosity and many others. You know the physical property of water that it boils at 100° C or that it has a density of 1 g/ml. A physical property, generally, is an aspect of a substance that can be measured or perceived without changing its identity and does not depend on the amount of that substance. For example, a gallon of ice has a melting point of 0° C and a small cup of ice also has a melting point of 0° C. The amount of the substance does not change it physical properties.

Answer these questions:

1. In an ice cube what is going on with the molecules of water?
2. In a cup of water what is going on with the molecules of water?
3. What happens to the molecules of water when the ice melts?
4. Does one molecule of water have a melting point? Why or why not?
5. After learning that diamonds are one of the hardest materials and that they are made of carbon atoms, your friend says, "Carbon atoms must be the hardest type of atom!" Respond to your friend. Do you agree? Disagree? Why?

Visit http://www.edinformatics.com/interactive_molecules/diamond.htm and learn about how carbon can be both diamond and the graphite in your pencil. While the substances have different properties, they are made up of the same atoms (Carbon), just arranged in a different way.

Purpose and Features of Elicitation and Diagnoser Questions

	Elicitation Questions	Diagnoser Questions
Purpose	• Motivate student interest in figuring something out (likely to be addressed in the next lesson) • Give teacher lay of the land with respect to range of student responses present in a class • Motivate student reflection: inform students about their understanding in relation to their peers	• Motivate student reflection about understanding of the concepts • Allow the teacher to check in on student learning and diagnose understanding in relation to facets • Motivate student reflection: inform students about their understanding in relation to targeted understanding
Administration Timing	Early in a unit prior to little, if any, teaching about the content	Mid-unit after some teaching about the content
Targeted Knowledge and Skills	Facets of student understanding	Facets of student understanding
Characteristic Features of Questions	• "Real world" and complex context • Connected to students' existing/prior knowledge and experiences • Multiple correct and/or partially correct plausible answers are possible • Multiple problematic answers are possible • Limited use of technical vocabulary	• One correct answer (for most items) • Multiple problematic answers are possible • Reasoning documented in selected or written response • Technology-supported • Use of technical vocabulary OK • Grade 4 reading level
Variable Features of Questions	• Delivered via technology (e.g., classroom response system) vs. paper-pencil vs. verbal by teacher • Selected response vs. constructed response	• Stand alone item vs. linked items • Selected response vs. constructed response • Use of technical vocabulary (e.g., low vs. moderate vs. high)
Types of Student Work Products	• Written constructed-response • Open-ended class discussion • Selected-response followed by class discussion	• Informal observations of student engagement in an activity • Selected- or constructed-response items with immediate feedback
Evaluation of Student Work Products	• Informal linking of responses to facets by teacher	• For selected-response items: automated link to facets • For constructed-response items: responses coded in relation to facets by the teacher
Qualities of Feedback	• Minimal • Delivered by teachers or peers	• For selected-response items: Immediate, automated feedback based on alignment of student response to facet coding • For constructed-response items: Teacher feedback based on mapping of student response to facets
Next Steps/ Contingencies	• Developmental Lessons • Whole class discussion about questions • Small group discussion about questions	Prescriptive Activities related to specific problematic facets

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Project site: http://chemfacets.sri.com/

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