# Ninth Graders' Chemistry Perceptions

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# Overview

This presentation is based on work conducted for the development of the curriculum titled “Foundation Science: Chemistry” by EDC’s Center for Science Education in 2003–2004.

# The Presentation Draws On the Following

- Review of misconceptions literature
- Pre- and post-testing of field test students
- Identification of persistent misconceptions held by tested students

# How Do We Identify Students' Prior Knowledge?

- Standards provide common goals and expectations.
- Assessment and educational research can show measures of student learning and can determine if standards are met.

# What Information on Prior Knowledge Is Available?

- There are large-scale assessment results. Large-scale assessments test many students but often use multiple-choice items and measure recall of concepts.

- There are research studies on misconceptions. These studies look at smaller numbers of students but probe their thinking more deeply by using open-ended items that measure application of concepts.

# What Is a Misconception?

The term “misconception” is “a view or opinion that is false or inaccurate because it is based on faulty thinking or understanding.”

(Source: Oxford English Dictionary)

# Other Important Reasons to Know About Misconceptions

- Many misconceptions are extremely persistent and, if unacknowledged and unchallenged, can hinder acquisition of further knowledge in a particular area of science.
- Knowledge of students' misconceptions in a classroom can provide a starting point for conceptual flow and can inform instruction.

# What Are Some of the Causes of Misconceptions in Science?

- The use of everyday language in scientific contexts.
- Over-simplification of concepts and the use of unqualified generalized statements and algorithms.
- Students' preconceptions from private world experiences.
- Confusion between overlapping similar concepts.
- Inadequate prerequisite knowledge.

# What Concepts Are Foundational for HS Chemistry Topics?

- States of matter depend on molecular arrangement and motion (Grades 6–8 McREL).
- Conservation of mass in physical and chemical change (Grades 6–8 McREL).
- Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties (Grades 6–8 McREL).

# What Does the Research Say About States of Matter?

- When cued to do so, about half of students will recall the molecular arrangements of different states of matter. However...
- When asked open-ended questions about changes of state, most students do not apply this knowledge. For example, one study (McElwee) shows that about 90% of eighth graders, after instruction in states of matter, still believed that boiling is the release of bubbles of air, heat, oxygen, and/or hydrogen.

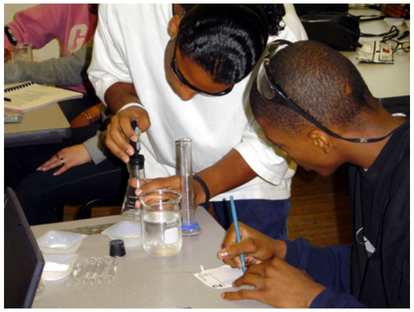
# What Does the Research Say About Chemical Reactions?

Many studies show that most students are unable to explain what occurs during a chemical reaction. However, most of these studies looked at chemical reactions in the context of rearrangements of atoms, not in the context of the formation of new substances with new properties.

# What Does the Research Say About Conservation of Mass?

- Different studies have shown that more than half of students entering high school do not believe that mass is conserved.
- Related research shows that students have confusion about the overlapping concepts of mass, weight, and density, and that about half of students do not believe that air is matter.

# The *Foundation Science* Field Test



Researched and tested students' conceptions in chemistry as part of our work on a ninth-grade half year chemistry curriculum.

- 37 classes in 31 schools across the country
- 771 student pre-tests analyzed

**Pre-Test Items Pertained To**:

- Physical properties
- Conservation of mass
- States of matter
- Chemical Reactions and compounds
- Atomic structure

Total of 26 pre-test items:

multiple choice (7), fill-in-the-blanks (2), open ended (17).

# Field-Test Results Correlated to Standards

| Standard | Question Type | Partial | Full |
| --- | --- | --- | --- |
| States of matter depend on molecular arrangement and motion | Recall | 10.5 | 49.8 |
| | Application | 24.7 | 15.3 |
| Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties | Recall | NA | 25.1 |
| | Application | 15.1 | 3.2 |
| | Application | 7.0 | 3.2 |
| | Application | 6.0 | 1.4 |
| Mass is conserved in physical and chemical change | Recall | NA | 42.1 |
| | Application | 8.2 | 2.6 |

# Example of a Question

**Question:**

Water's molecular structure consists of hydrogen and oxygen. Even though hydrogen by itself is a flammable gas, explain in 3–5 sentences why you cannot burn water.

- Is an open-ended question.
- Can be answered at different levels of understanding (macro vs. micro).
- Reveals student's prior knowledge (if substances react chemically, a new substance is created with new properties).





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# Some Student Answers

**Student 1 Response**:

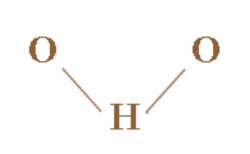
“Because when combined they make a watery substance.”

**Student 2 Response:**

“Hydrogen is flammable and can burn easily, but when added to oxygen it can’t burn. Oxygen dilutes the hydrogen and makes it not as flammable.”

**Student 3 Response:**

“In water, there is one part hydrogen and two parts of oxygen.




A fire can burn hydrogen but not oxygen. Since there is more oxygen, hydrogen is overruled.”

# Steps to Analyze Student Answers

1. Identify the criteria for a complete answer.

**Expectation in the "Water" Example**:
Criteria 1: Elements gain, lose, or share electrons when they form a compound or undergo a chemical reaction.
Criteria 2: Compound formed has different properties from its component elements.

2. Develop a scoring rubric.
Brainstorm potential student answers and group them into three categories:

Correct = full points
Partially correct = half of the points
Incorrect = no points

3. Refine rubric while scoring student answers; keep track of the nature of their wrong ideas/reasoning/or causal relationships they make.





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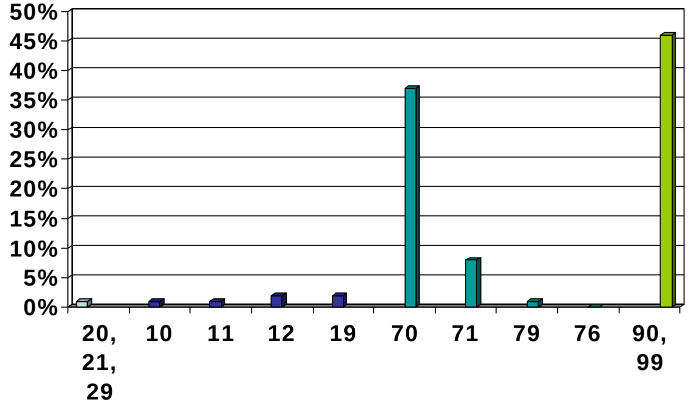
# Sample Scoring Rubric

| Code | Response |
|---|---|
| **20** | **Response meets both criteria.** |
| **21** | **Response meets criteria but makes no explicit mention of electron transfer or sharing.** |
| **29** | **Any other complete explanation.** |
| **10** | **Explains criterion # 1 but omits or makes an error in criterion #2.** |
| **11** | **Explains criterion #2 but omits or makes an error in criterion #1 (such as omitting that a new substance is formed).** |
| **12** | **States only that properties of compounds are different from properties of their component elements without explaining why.** |
| **19** | **Any other partially correct response.** |
| **70** | **Fails to make any distinction between properties of elements and those of compounds made up of those elements.** |
| **71** | **Refers to reactants mixing, combining, neutralizing, canceling, or attacking each other without reference to chemical change or to the formation of a substance.** |
| **76** | **Repeats question or answer to a previous question but fails to answer this question.** |
| **79** | **Any other incorrect response.** |
| **90** | **Off task, irrelevant, illegible, scratched out or otherwise uninterpretable.** |
| **99** | **BLANK.** |

# Information Gained from Answers

=> **Quantitative Analysis**: Field-test data revealed that only 7% of all students received full or partial credit on this question (1% and 6% respectively).




=> **Qualitative Analysis**: Answers revealed areas of confusion, wrong prior knowledge, and wrong connections to other science knowledge.

**Identified Problematic Areas:**

- Confusion about state of matter and properties ("liquids don't burn").
- No distinction between properties of elements and those of compounds made up of these elements.
- Reference to mixing/adding instead of a chemical reaction.
- Notion of neutralizing/overpowering properties.

# Opportunity to Practice Identifying Student Problems

**Example 1: (middle school concept)**
**Question:**
In 3-5 sentences, explain why table salt, chemically known as sodium chloride, can be used on food when pure sodium is a very dangerous soft metal and pure chloride is a poisonous gas.

**How would you interpret these answers?**
“Because table salt isn’t pure sodium chloride, it has something either added to it or taken away to make it safe.”
“When proportioned so it has a bit of taste rather than in a larger quantity that could be poisonous.”

# Opportunity to Practice Identifying Student Problems

**Example 2: (high school concept)**
**Question:**
In 3-5 sentences, give an explanation as to why a salt solution is a better conductor of electricity than a sugar solution.

**How would you interpret these answers?**
"Salt has $Na^+$ and $Cl^-$ when dissolved into a glass of water. Both are conductors of electrons. $C_6H_{12}O_6$, will be broken down into non-conductive elements C, H and O."

# Findings in a Nutshell

Example 1: Sodium Chloride Question:

The problem areas were:

- No distinction between properties of elements and those of compounds made up of these elements
- Reference to mixing/adding instead of a chemical reaction; difference between elements and compounds
- Notion of neutralizing/overpowering properties
- Meaning of “**pure”** in science vs. everyday use

=> Field-test data revealed that only 10% of all students received full or partial credit on this question (3% and 7% respectively).

Example 2: Salt vs. Sugar Solution:

The problem areas were:

- Problems making transfer from nature of bonds to particles found in solution
- Conductivity of salt attributed to the presence of sodium metal
- Conductivity of salt solution attributed to moving electrons rather than ions

=> Field-test data revealed that only 1.4% of all students received full or partial credit on this question (.1% and 1.3% respectively).

# Another Example

**Example 3: (high school concept)**
**Question:**
The following chemical equation is a simplified reaction between carbon (C) and oxygen ($O_2$) to form carbon dioxide ($CO_2$). The mass below each element tells you the amount of carbon and oxygen needed to produce a certain amount of carbon dioxide.

$$C + O_2 \rightarrow CO_2$$

(12g 32g → 44g)

If you have 30 grams of carbon and 30 grams of oxygen, can 44 grams of carbon dioxide still be made? Explain in 3-5 sentences.

**=> Open-ended question**
**=> Requires students to apply the following concepts:**

- Conservation of mass
- Balanced equations (stoicheometry)
- Fixed ratios (law of definite proportions)

# Revising Misconceptions — Easier Said than Done

**Hard to reveal misconceptions, but even harder to revise them.**

**Why is it so hard?**

- Natural for humans to try to make sense of what we see. But making sense of things around us is NOT the same as being right.
- Misconceptions often go unnoticed, unchallenged, or are too entrenched.
- Often when we try to overwrite misconceptions we do not deal with the underlying belief system.
- Science concepts are complex and very often NOT intuitive.

**=> What does it take to support students in mastering complex science concepts, in particular, if it requires changing entrenched misconceptions?**

# Modify Student's Belief System

**Some Thoughts from the Metacognition Literature:**

- Can take a LOT of time! All minds are different – to find optimal form, one needs to assess the exact misconception, recognize possible resistance, and find optimal form of new information and method.
- Construct experience that challenges underlying mental representation at the right complexity level!

**Three conditions have to be met:**

1. Misconceptions have to be directly confronted. Resistance must be clearly recognized and dealt with.
2. Approach and present content/concepts in different ways and contexts.
3. Individuals must absorb themselves deeply in examples.

*(Source: Howard Gardner: Changing Minds)*

# Some Suggestions for the Classroom

- Be aware of how misconceptions can stand in the way of new learning.
- Pay close attention to students' explanations (not only in tests).
- Challenge students' misconceptions; be aware of potential resistance.
- Encourage students to hypothesize, design experiments, and participate in "scientific discourse."
- Probe students' thinking.
- Model scientific thinking rather than telling the facts.
- Foster conceptual understanding to reach underlying belief system.
- Provide different contexts in which concepts can be applied.
- Use different ways to package the same concept.

=> Many effective formats to reach the tipping point. Be creative and patient.

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