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The Nature of Science in the Science Classroom

What the Research Says

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What do you think?

Turn to a neighbor and sketch a Venn diagram that shows the commonalities and differences of

- Science as scientists do it
- Science in the high school classroom



“Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study.”

(AAAS, 1989)



What are the characteristics of science that set the stage for school science?

- Scientists believe that **the world is understandable**.
- Science is not the search for the truth, but the search for more precise ways to **explain and predict** how the world works.
- The practice of science employs **logical reasoning** to connect evidence with conclusions.
- Science is all about **sense-making**—using logical reasoning to connect observations and data with accepted scientific explanations.

(AAAS, 1989)



Specifically, science

- demands evidence.
- is a blend of logical reasoning and imagination.
- explains and predicts.
- ideas are subject to change.
- knowledge is durable.
- cannot provide complete answers to all questions.

(AAAS, 1989)



California State Standards

Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations....
Students will

D. Formulate explanations by using logic and evidence.

F. Distinguish between hypothesis and theory as scientific terms.

G. Recognize the usefulness and limitations of models and theories as scientific representations of reality.

J. Recognize the issues of statistical variability and the need for controlled tests.

K. Recognize the cumulative nature of scientific evidence.

L. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

M. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings.

N. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent.



Research About Inquiry-based Learning



How People Learn

1. Learners come to class with preconceptions.
2. Learner need to develop a deep factual understanding based in a conceptual framework.
3. Learners set goals and analyze progress toward them.

(NRC, 2000)



Using Explanations to Increase Learning

- Explanations are rarely a part of classroom practice, but students need to be explicitly taught about explanations.
- Students have difficulty using appropriate evidence and including the backing for why they chose the evidence in their written explanations.
- Students typically discount data if the data contradicts their current theory.
- During classroom discourse, discussions tend to be dominated by claims with little backing to support their claims.
- Understanding of scientific principles is linked to ability to develop explanations.

(McNeil et al, 2006)



Research about Curriculum Materials and/or Instruction



Teacher Knowledge of Inquiry

In a survey of 74 university graduates with science degrees who wanted to become teachers

- 76% equated a fact with “truth” and “proven”
- 61% recognized that hypotheses were predictive and testable in nature
- 47% recognized a theory as an explanation supported by a preponderance of evidence
- 23% defined a theory as “unproven ideas” or “an idea based on little evidence; not fact; not necessarily true”
- 11% defined a fact as evidence or data

(Williams, 2008)



Teacher Practice

In a survey of 5,278 teachers

- Teaching practices and student objectives characteristic of inquiry consistently occurred with less frequency and emphasis than traditional teaching methods and learning goals
- Only 12% of HS teachers said that they had “implemented recommendations from the National Education Standards in [their] science teaching” to a great extent.

(Hudson, et al, 2002)



Inquiry and Classroom Management Concerns

Teachers cited these issues as serious problems when trying to use inquiry-based approaches

- Students do not participate enough.
- Students do not know how to get the inquiry started.
- Students do not care and do not see the inquiry as relevant to their lives.

(Lawson, A.F., 2000)



Fidelity of Implementation

- Inquiry-based instructional materials must be implemented with high or medium fidelity to improve student learning.
- Inquiry-based instructional materials implemented with low fidelity result in learning gains equal to traditional materials.

(Coulson et al, 2007)



The Influence of Teacher Beliefs

Teachers are more likely to implement inquiry-based instructional materials with high or medium fidelity if they believe that

- Science is a way of understanding the world.
- The teacher's role is to guide students toward understanding.
- Students are responsible for their own learning and all students are capable of learning.

(Carlson Powell, 1999)



A Key Characteristic of Effective Inquiry Instruction

Effective inquiry-based instruction relies on significant scaffolding to guide student learning, and commonly involves timely direct instruction.

(Krajcik, Czerniak, & Berger, 1999; Schmidt, 1983; Schwartz & Bransford, 1998)



Curriculum Materials

A study by that found that students using the inquiry-based GenScope™ learning environment showed significantly higher learning gains than students in comparison classrooms that did not incorporate inquiry-based strategies and materials.

- Using performance on state standardized tests as the measure of student learning urban middle school students using the GenScope™ inquiry-based materials had **significantly higher pass rates** among compared to students using the traditional materials.
- The effects were both **cumulative** (more exposure to inquiry-based units resulted in higher achievement on the tests) and enduring (the learning gains were evident a year and half after participation in the units).

(Geier et al., in press; Hickey, Kindfeld, Horwitz, & Christie, 1999)



Curriculum Materials and Instruction

A study involving 1,800 students and 24 teachers from seven schools compared the learning gains in middle and high school students after being taught a forensic unit by either inquiry-based or traditional approaches.

- This study **showed significantly higher post-test scores among the students taught by a guided inquiry approach** as compared to students taught by traditional methods.

(Blanchard et al., 2008)



Achievement Gaps and C&I

Several studies state that

- Teaching science as inquiry reduces gaps (Kahle, Meece, & Scantlebury (2000); Marx et al. (2004)

Specifically Kowalski et al (2009) found that

- Students using the curriculum demonstrated large, significant learning gains from pretest to posttest and the gains were *not dependent* on a student's membership in any specific group (FRL status, race/ethnicity, or gender) once math level and pre-test score had been taken into account.



Results of an Experimental Study by BSCS

Equal numbers of students were randomly distributed into treatment and control groups. The treatment group experienced science instruction about sleep based on the 5Es and inquiry. The control group learned about sleep through commonplace teaching practices. The teacher, content, instructional time, and assessments were held constant. Results showed that

- Students in the inquiry-based group had **significantly higher posttest** scores than students in the commonplace group.
- The commonplace unit resulted in significantly lower posttest scores for non-whites, yet **no significant difference by race** was present in the posttest scores of students in the **inquiry-based group**. There was also no significant differences in the pretest scores of white and nonwhite students in either group.
- Students in the inquiry group had significantly higher scores for **claims and reasoning** than students in the commonplace group.

(Taylor et al, 2009)



Summary of C&I Findings

- Teacher knowledge matters.
- Teacher beliefs matter.
- Curriculum materials can support the teaching of inquiry.
- Classroom management needs to be addressed.
- Curriculum materials can eliminate achievement gaps.
- Inquiry-based instruction can eliminate achievement gaps.
- Inquiry-based instruction supported by materials produces the most compelling results for learning.



Research About Assessment



The Effects of High-Stakes Assessment

Some have argued that standardized testing has

- resulted in teaching practices that are at odds with those advocated in the national science education reform documents.
- had negative effects on science teachers' perceptions of the quality of their teaching.
- created pressures for teachers to prepare students for tests that cover large amounts of content and emphasize factual knowledge.

(Blanchard, Annetta, & Southerland, 2008; Shaver, Cuevas, Lee, & Avalos, 2006; Southerland, Abrams, & Hutner, 2007; Whitford & Jones, 2000)



Assessment Results

“Most studies I examined supported the collective conclusion that inquiry-based instruction was **equal or superior to** other instructional models for students producing higher scores on content achievement tests.”

(Colburn, 2008)



Evidence “Against” Inquiry

A small number of studies offer evidence against the effectiveness of inquiry-based materials and teaching:

- Pure discovery teaching methods can lead to **frustration** (Hardiman, Pollatsek, & Weil, 1986; Brown & Campione, 1994)
- Discovery learning is **inefficient** because it can lead to false starts (Carlson, Lundy, & Schneider, 1992; Schauble, 1990)
- Direct instruction is more effective than discovery learning for **acquiring factual knowledge** (Moreno, 2004).
- Teachers taught units either by direct instruction, guided inquiry, or a hybrid of the two. The mixed approach was the most successful for increasing subject matter knowledge, knowledge of scientific inquiry, as well as attitudes towards science; however the differences were **not statistically significant** for any of the approaches. (Lederman et al., 2008)



The Most Compelling Data Indicate That

- Inquiry-based curriculum and instruction must be used together.
- High quality inquiry-based C&I are distinguished by features such as
 - an overt and planned learning sequence – not random discovery learning;
 - A coherent flow of ideas with factual information intentionally connected to larger concepts and contexts;
 - Carefully scaffolding students' opportunities to develop the abilities to conduct inquiries; and
 - Emphasizing how to develop scientific explanations.



Barriers & Challenges

The barriers to teaching inquiry fall into three main areas:

- *Political dilemmas* (such as parental resistance and conflicts between teachers),
- *Cultural dilemmas* (such as differing beliefs and values about learning and assessment), and
- *Technical dilemmas* (which include limited abilities to teach and assess).

(Anderson, 2002)



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