Understanding Science: Improving instruction on the nature and process of science

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It is essential for the public to understand how to think critically about evidence...

consumer choices

court cases

The Evolution Controversy
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The public needs to understand the characteristics of scientific evidence....

Unfortunately, they do not:

• “Most Americans do not understand the scientific process and therefore may lack a valuable tool for assessing the validity of various claims they encounter in daily life.” (Science and Engineering Indicators, 2006)
Understanding Science

how science really works

Get to know us, take our site tour, or subscribe for updates.

See a visual representation of the process of science.

Asteroids and dinosaurs
One geologist's surprising observation started science on an unexpected journey of discovery toward solving the mystery of the dinosaur extinction. Learn more about how science works as you follow the twists and turns of this scientific adventure.

Fair tests: A do-it-yourself guide
Find out what makes a fair test in science and how you can make use of the same ideas.

Your science toolkit
Use this set of tips to separate science from spin in the media and in public policies.

Resource library

Teaching resources — find classroom activities, teaching tools, a K-16 conceptual framework, tips, and strategies for integrating the process of science into your teaching, and more.

Correcting misconceptions — clear up common misconceptions about the nature of science.

Science talk

"In the long run, the greatest gift of science may be in teaching us in..."
Developed by the UC Museum of Paleontology in collaboration with . . .

**Teacher Advisory Board:** Jen Collins, Bob Connell, Peg Dabel, Deb Farkas, Stan Hitomi, Al Janulaw, Sharon Janulaw, Mark Stefanski, Mark Terry, Cecilia Tung

**Project Advisory Board:** Max Bronstein, Sam Donovan, Anne Egger, Jack Hehn, Sharon Janulaw, Natalie Kuldell, Norman Lederman, Tania Lombrozo, Ian MacGregor, Richard O'Grady, W. Geoffrey Owen, Mark Richards, Edward Robeck, Walter Snyder, Mark Stefanski, Richard Stucky, Mark Terry, Michael Weisberg, Lisa White, Lori Zaikowski
Understanding Science is a web-based project that aims to:

• improve teachers’ understandings of the scientific enterprise

• provide resources and strategies that inspire and enable teachers to reinforce key concepts regarding the nature and process of science throughout their science teaching

• provide a comprehensive and clear reference for students and the general public that portrays the true nature of the scientific endeavor
Understanding Science provides tools for exploring the power and limits of science.
A new and more accurate approach to the process of science
Understanding Science addresses how science shapes and is shaped by society.

Science and society

Societies have changed over time, and consequently, so has science. For example, during the first half of the 20th century, when the world was enmeshed in war, governments made funds available for scientific research with wartime applications — and so science progressed in a particular direction, unlocking the mysteries of nuclear energy. In contrast, today, money is invested in medical treatment, drug production, and agriculture, some corporations have increasingly devoted research dollars to biotechnology research, yielding breakthroughs in genomic science and genetic engineering. And on the flipside, modern foundations and other financial success of individuals may invest their money in ventures they deem to be socially responsible, encouraging research on topics such as disease in developing countries. Science is not static; it changes, reflecting shifts in the larger societies in which it is embedded.

Knowledge of the atomic nucleus has been applied in many different ways: nuclear power, medical imaging, weapons.
Understanding Science addresses how to analyze science-related media messages.

A scientific approach to life: A science toolkit

Trans-fat free! Ethanol production: an eco-nightmare? Cancer researchers discover new hope. Major petroleum company acknowledges reality of global warming. Clinically proven to reduce the appearance of wrinkles! These aren’t exactly the headlines you’d find in a scientific journal, but they are examples of the sorts of scientific messages that one might encounter everyday. Because science is so critical to our lives, we are regularly targeted by messages about science in the form of advertising or reporting from newspapers, magazines, the internet, TV, or radio. Similarly, as discussed in Science and society, our everyday lives are affected by all sorts of science-related policies — from what additives are allowed (or required) to be mixed with gasoline, to where homes can be built, to how milk is processed. But don’t have to take these media messages and science policies at face value. Understanding the nature and process of science can help you uncover the real meaning behind media messages about science and evaluate the science behind policies.

Ethanol production: an eco-nightmare?

Where does the information come from?
Are the views of the scientific community accurately portrayed?
Is the scientific community’s confidence in the ideas accurately portrayed?
Is a controversy misrepresented or blown out of proportion?
Where can I get more information?
How strong is the evidence?
Guiding pedagogical principles

• Make the nature and process of science explicit
• Help students reflect
• Give the nature and process context, again and again.

(Lederman, 1998)
Evaluation overview

25 middle and high school teachers in Colorado:
• attended a one-time, 6-hour in-service workshop on Understanding Science
• implemented lessons and strategies from the website in their own classrooms
• participated in evaluation activities throughout the course of one academic year
• collected data from their students (n=1287)
Evaluation Questions

• Does using Understanding Science materials increase teachers’ understanding, confidence, and comfort in teaching the nature of science?
• Does using the Understanding Science materials and concepts in the classroom impact student knowledge and attitudes toward science?
• Is the impact of these materials equitable across different demographic variables?
Timeline of intervention

Classroom implementation: teachers complete specified activities with students

- Pre-test
- 3 required activities
- Post-test

Fall 2009
Spring 2010
Optional implementation: teachers were invited to employ additional activities and strategies from Understanding Science as they wished

• Maintained log of these activities
• Administered a post-post test (all students)
Instruments used with teachers

- Survey on attitude and practice regarding teaching the nature/process of science
- Likert-style assessment of knowledge and attitudes regarding the nature/process of science
- Focus group at BSCS to reflect on experience thus far
- Survey on overall experience of the intervention

Fall 2009 to Spring 2010
Instruments used with students

- Modified Attitudes Toward Science Inventory (mATSI; Weinburgh & Steele, 2000)
- Nature/process of science test
- Demographics survey
Results: High levels of teacher buy-in

- Teachers indicate positive changes in how they communicate the nature/process of science to students
- Teachers report continuing change in their teaching of these topics
- Teachers report decrease in dependence on textbooks ($t(22) = -2.08, p < .05$)
- Several self-report indicators of teaching style show no change or undesirable change.
  - Reinforcing nature-of-science concepts less often ($t(22) = -3.28, p < .01$)
  - No change in allowing students to pursue different investigations simultaneously
  - No change in the timing of the introduction of nature-of-science concepts
Results: Teacher participants had an accurate understanding of nature/process of science

- On the pretest, teachers had a very favorable beliefs and attitude towards the nature/process of science.
- Unsurprisingly, teachers did not substantially improve their understanding over the course of the evaluation:
  - only two items of 38 had statistically significant changes and for one of those items, the change was in an undesired direction
  - only 30.4% reported that their own views of the nature/process of science had changed as a result of the workshop
Results: No consistent or substantial changes in student attitudes towards science

- Perception of science teacher, anxiety about science, perceived value of science, self-concept of science, and desire to do science were examined (mATSI)
- All significant changes in student attitude were small, with Cohen’s $d$ Effect sizes below 0.3
Results: Significant student learning regarding the nature/process of science

<table>
<thead>
<tr>
<th></th>
<th>Pretest mean</th>
<th>Posttest mean</th>
<th>t-test</th>
<th>Effect Size (lower, upper CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Middle school</strong></td>
<td>15.31</td>
<td>21.99</td>
<td>( t(487) = 45.14, p&lt;.001 )</td>
<td>2.08 (1.92, 2.23)</td>
</tr>
<tr>
<td><strong>High school</strong></td>
<td>16.72</td>
<td>23.24</td>
<td>( t(353) = 42.20, p&lt;.001 )</td>
<td>2.11 (1.93, 2.29)</td>
</tr>
</tbody>
</table>

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</thead>
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<tr>
<td><strong>Middle school</strong></td>
<td>15.45</td>
<td>22.32</td>
<td>( t(401) = 35.99, p&lt;.001 )</td>
<td>1.89 (1.72, 2.05)</td>
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<tr>
<td><strong>High school</strong></td>
<td>16.6</td>
<td>23.48</td>
<td>( t(304) = 42.50, p&lt;.001 )</td>
<td>2.38 (2.17, 2.58)</td>
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</table>
Knowledge gains appear to be equitable across most, but not all demographic groups:

- White and Asian students made larger gains during the optional implementation period than did students in other groups.
Results: Student knowledge gains appear to be improved by more extensive implementation.

After the initial classroom implementation period, we used multi-level modeling (HLM) to predict student scores using pretest score as a covariate.

<table>
<thead>
<tr>
<th></th>
<th>coefficient</th>
<th>standard error</th>
<th>t-ratio</th>
<th>p-value</th>
<th>Hedges’ g</th>
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<tr>
<td>Pre-test</td>
<td>1.00</td>
<td>.08</td>
<td>13.27</td>
<td>.000</td>
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<tr>
<td>Teacher implementation</td>
<td>.07</td>
<td>.25</td>
<td>.27</td>
<td>.788</td>
<td>.06</td>
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</table>

As expected, only pretest score was a significant predictor of performance on the mid-year knowledge assessment.
Results: Student knowledge gains appear to be improved by more extensive implementation

Model 2 attempted to predict student scores at the end of the year based on pretest score and teacher implementation of materials during the optional implementation period:

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<th>p-value</th>
<th>Hedges’ g</th>
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<td>Teacher implementation</td>
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<td>.27</td>
<td>4.14</td>
<td>.000</td>
<td>.50</td>
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</table>

Both pretest and teacher implementation level predicted performance on the end-of-year knowledge assessment.
Summary of findings

• High level of teacher buy-in regarding improved emphasis and instruction on the nature and process of science
• Little increase in teacher understanding of these concepts
• Meaningful increases in student understanding of the nature and process of science
• Reports from teachers of increases in student engagement and motivation