MOSART: From MSP to teacher to student

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Summary

• This session focuses on two sets of research findings:
  – The effects of MSP institutes on teachers' subject matter knowledge and pedagogical content knowledge
  – the effects of teacher knowledge on student gains.
• Misconceptions are robust but scientifically inaccurate understandings of the world that are often consistent with everyday experience.
• We have developed a unique approach to measuring teachers’ SMK and PCK in a large scale study that clarifies the relationship between teachers' knowledge of misconceptions and students' gaining better understanding.
  – To measure teachers’ subject matter knowledge (SMK), teachers take the same test as their students.
  – Pedagogical content knowledge (PCK), is revealed by asking teachers to predict the most common wrong answer chosen by their own students.
• We have analyzed data from more than 400 teacher participants engaged in more than 20 institutes in many states throughout the U.S.
How do you rigorously measure conceptual understanding of teachers and students?
How do you rigorously measure conceptual understanding of teachers and students?


Scale Model of the Solar System
On-on-one with students

A Private Universe documents students’ ideas through their own drawings and explanations

Minds of Our Own consists of 3-one hour programs broadcast on PBS in 1997-98. It explores the ideas of students as they come to understand scientific concepts

www.learner.org
Both students and teachers have (or had) preconceptions

- Exist prior to formal instruction
- At odds with accepted scientific thought, "misconceptions"
- Commonly held, not idiosyncratic
- Embedded in larger knowledge structures, not just a simple "error" (that is easy to correct)
- Resistant to change, overestimation of $\Delta$
- Originally catalogued as "math bugs"
- Preconceptions forgotten as knowledge is restructured
Steps in instrument development based on student ideas

- Employ NRC standards, the root of state standards
- Construct assessment instruments based on misconceptions
  - Research literature
- Validation with both students and teachers
  - Pilot and field tests
  - Final instruments
- Measure both SMK and PCK
What is the cause of day and night?

NAEP 3rd grade

SED 8-12th grade
What is the cause of day and night?

NAEP 3rd grade
a. Earth turns.
b. Sun turns.
c. Moon turns.
d. Sun gets dark at night.

e. I don’t know.

SED 8-12th grade
What is the cause of day and night?

NAEP 3rd grade
a. Earth turns. (81%)
b. Sun turns. (8%)
c. Moon turns. (4%)
d. Sun gets dark at night. (6%)
e. I don’t know. (1%)

SED 8-12th grade
What is the cause of day and night?

NAEP 3rd grade
a. Earth turns. (81%)
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SED 8-12th grade
a. The earth spins on its axis.
b. Clouds block the sun’s light
c. The earth moves into and out of the sun’s shadow.
d. The sun goes around the earth.
e. The earth moves around the sun.
What is the cause of day and night?

NAEP 3rd grade
a. Earth turns. (81%)
b. Sun turns. (8%)
c. Moon turns. (4%)
d. Sun gets dark at night. (6%)
e. I don’t know. (1%)

SED 8-12th grade
a. The earth spins on its axis. 68%
b. Clouds block the sun’s light
c. The earth moves into and out of the sun’s shadow.
d. The sun goes around the earth.
e. The earth moves around the sun.
What is the cause of day and night?

NAEP 3rd grade
a. Earth turns. (81%)
b. Sun turns. (8%)
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d. Sun gets dark at night. (6%)
e. I don’t know. (1%)

SED 8-12th grade
a. The earth spins on its axis. 68%
b. Clouds block the sun’s light 0%
c. The earth moves into and out of the sun’s shadow. 3%
d. The sun goes around the earth. 4%
e. The earth moves around the sun. 26%
Reason for Day and Night

- The earth spins on its axis. (C) 68%
- The earth moves around the sun. 26% (M1)
- The sun goes around the earth. 4%
- The sun goes into and out of the sun's shadow 3%
- Clouds block out the sun's light. 0%
The earth spins on its axis. (C) 68%

The earth moves around the sun. 26% (M1)

Clouds block out the sun's light. 0%

The sun goes around the earth. 4%

The earth moves into and out of the sun's shadow 3%
Our Criteria for Conceptual Understanding

Students and teachers must:

- Prefer accepted scientific explanations over widely-held misconceptions
  - Item must contain both
- Apply their knowledge to make accurate predictions
  - Can concept be used?
Test Construction
How do you move from clinical interviews to distractor-driven, multiple-choice items?

Breakdown of Standards into component concepts
   Identify all relevant misconceptions reported in the literature
   Interview in areas for which the literature is sparse

Item Construction
   Write stem, correct answer, misconceptions,

Validation
   Are the questions accurate in terms of the science? Readable?

Pilot Testing (N=100/item)
   selection of core items that represent the most variance

Large scale sample (N=1000/item)
   Item characteristics for 100-200 items/domain @$2k/item

Finalization of Instruments
   Made available for evaluation of programs, pre-/post-tests
## Test Instruments Available at the MOSART Website

<table>
<thead>
<tr>
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<th>K-4</th>
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What is the State of Teacher and Student Knowledge?
There are different objects in the sky. The sun heats the earth. There are many stars in the sky. Objects in the sky have patterns of motion.
The solar system has a star, planets and other objects. Solar system objects move predictably. Gravity is the key force in the solar system. The sun’s energy underlies many terrestrial phenomena. Stars are fixed relative to each other. Planets move relative to the stars. Telescopes extend our vision. Stars are clustered in galaxies. Light takes time to travel.

Middle School Astronomy Standards
High School Astronomy Standards

- The "big bang" theory
- Early star and galaxy formation
- Stellar fusion and its effects
- Stellar variation
- Light element formation
- Heavy element formation
- Obtaining and analyzing astrophysical data

NRC Standard

Graph showing the fraction correct for various topics among students, teachers, and predictions.

- Students
- Teachers
- Predictions
HS Chemistry

Diagram showing data points for different categories:
- Students
- Teacher SMK
- Prediction

Categories include:
- I.A: Matter Discontinuous
- I.B: Atomic Structure
- I.C: Nuclear Structure & Reactions
- II.A: Radioactive Isotopes
- II.B: Elements & Periodic Table
- II.C: Atoms & Bonds
- II.D: Properties of Compounds
- II.E: Carbon Atoms
- III.A: Chemical Reactions
- III.B: Chemical Reactions & Energy
- III.C: Chemical Reaction Types
- III.D: Chemical Reaction Rates
- III.E: Catalysts
I. Structure and function in living systems
II. Reproduction and heredity
III. Regulation and behavior
IV. Populations and ecosystems
V. Diversity and adaptations of organisms

Students
Teacher Prediction
Teachers

MOSART Middle School Life Science Field Test
Patterns in Test Data
Item Characteristics
Difficulty vs. Discrimination

Difficulty (Fraction Correct)

Discrimination (Correlation with Total Score)

-0.25 0.00 0.25 0.50 0.75 1.00

9-12

5-8

K-4
Comparison of Item Formats with and without strong misconception

- 76. Electric Cord
- 68. Refraction of laser
- 61. Weight Loss
- 21. Mass of Baking Soda + Vinegar
- 13. Candle wax

- 0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

Legend:
- Pink: with misconception
- Gray: without misconception
Relationship between Teacher and Student Knowledge

![Graph showing the relationship between teacher performance and student performance. The graph includes a scatter plot with data points and a trend line, indicating a positive correlation.]
How well do teachers predict student knowledge?
Performance on MOSART Assessment of 196 Middle School Physical Science Teachers
K-4 and 5-8 LS Teacher Knowledge

Teacher Knowledge MOSART
K-4
Life Science Pilot

Teacher Knowledge MOSART
5-8
Life Science Pilot
Research Uses of the ASCII Instruments
Results of a Year of Instruction

Grade Band of Standards

- K-4
- 5-8
- 9-12

MS Pre-test
MS Post-test
Results of a Year of Instruction

Grade Band of Standards:
- K-4
- 5-8
- 9-12

Graph showing pre-test and post-test scores for HS Pre-test and HS Post-test across different grade bands.
Yearly Classroom Gain in Middle School Physical Science Courses, N= 15029 students of 160 teachers

<table>
<thead>
<tr>
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**Item Type and Teacher Knowledge**

SMK=Subject Matter Knowledge (knows correct answer)
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Yearly Classroom Gain in Middle School Physical Science Courses, N=15029 students of 160 teachers

Concepts without Strong Misconceptions

Concepts with Strong Misconceptions

Effect Size (in Units of Standard Deviation)

No SMK | SMK

No SMK | SMK Only | SMK & PCK

No Misconception | Misconception

Item Type and Teacher Knowledge

SMK=Subject Matter Knowledge (knows correct answer)
PCK=Pedagogical Content Knowledge (can identify student misconceptions)
Results of Teacher Professional Development
1-Week Astronomy Institute

- Instrumentation
- Earth-Sun connection only
- Only relevant items
- Speakers
- Activities
- Observing
1-Week Astronomy Institute

- Learn to use professional instrumentation
- Disciplinary domain focus
- Speakers
2-Week Astronomy Institute

- Basics
- To boost astronomy background
- General astronomy test
- Speakers
- Activities
- Observing
2-Week Astronomy Institute

- Moderate initial knowledge
- Gains at all levels of teacher knowledge
- Few teachers with no or negative growth
1-Week Astronomy Institute

- High initial knowledge
- No gains at highest level of teacher knowledge
- Many teachers with no or negative growth
Comparison of 2 MSP Institutes

Astronomy Form 611 Pre-

Astronomy Form 611 Pre-

Pretest total

Posttest total
Astronomy Institutes, SMK

Gain in Teacher Subject Matter Knowledge

Effect Size (gain in units of standard deviation)

Institute Identifier

error bars=±2SE
Next Steps: Attribution of Gains to Institute Attributes
Teacher Views of Effectiveness

- Teaching practices used were effective for me
- Teaching practices modeled would be effective for my students
- Deepened my understanding of current research in LS
- I found my ideas about how to teach LS changing
- Connected well with the topics or curriculum I teach
- Deepened my knowledge of scientific topics I teach
- I will continue to contact colleagues from program
Variation in Institute Activities
Institute-level

Frequency of Activities

- Lectures and workshops by Scientists
- Conducting/Assisting in Research
- Cutting Edge Science
- Existing Foundations
- Developing Curricula
- Technology
- Collaborating with colleagues
- Active Learning
- Assessing student work
- Observing or Critiquing Teaching
- Developing Assessments
- Misconceptions
- Designing Field Trips
- Inquiry
Growth in Teachers' Subject Matter Knowledge
Middle School Life Science Summer Institutes, N=113, 11/17/10

Effect Size

Institute

error bars=±1SE
Growth in Teachers' Pedagogical Content Knowledge
Middle School Life Science Summer Institutes, N=113, 11/17/10

Effect Size

Institute

error bars=±1SE
Assessment and PD

For each standard at each level
- Students have not achieved mastery
- Teachers generally overestimate student knowledge.
- Teachers know far more than their students
- Teacher knowledge is a not a guarantee of student knowledge
- Subject do much better on items if misconceptions are not a choice

- SMK and PCK not highly related to each other
  - Both predict performance
- PD can have varying degrees of effectiveness
  - Advanced activities have little effect on basic conceptual understanding
  - Experience has little impact on understanding student difficulties
Key Findings

- Institutes vary in the pre-post gains made by teachers in both SMK and PCK.
- Length of time spent on various participant activities, rather than more formal (passive) learning, improves both SMK and PCK.
- Students taught by teachers who have SMK are more likely to change their conceptions than students of teachers who do not know the correct response.
- Students of teachers who accurately predict the most common incorrect response to an item are more likely to reject that conception and embrace the scientifically correct response.
Key insights that have value for the Learning Network

• With our new online testing system, we expect to provide early useful pre-test results to participating MSPs. The first report will be a “diagnosis” of participants’ areas of strength and weakness.

• The use of MOSART assessments will allow us to compare the gains made by one institute's participants to other institutes targeting the same content and thus facilitate the sharing of practices.

• Using robust, technically validated assessment data minimizes the problems of “apples and oranges” in comparing MSPs. In addition, entirely idiosyncratic measures are often qualitative, and may be biased, as well as difficult to evaluate. With a common evaluation suite, NSF can gain better understandings of what MSPs are accomplishing.
Publications


Welcome to MOSART

“‘I’m teaching, but they’re not learning!’

This is one of the most common laments from educators. Your students may perform well on your assessment instruments, yet say things in class which leave you wondering if they really understand the underlying concepts. Or perhaps you’re at the beginning of a unit and are unsure about what your students already know. Which concepts do they already grasp, and which will you have to address? If any of these doubts and questions sound familiar, then the MOSART project was designed to help you.

The acronym MOSART stands for:

- **Misconceptions-Oriented**: The project recognizes that students do not come to your class as “blank slates” but rather have their own theories.
- **Standards-based**: The NRC NSES comprise a unifying thread among all MOSART items and tests.
- **Assessment Resources for Teachers**: The project provides educators with multiple-choice tests that can be used to assess their students’ understanding of this content.
Acknowledgments

- Co-investigators: Matthew Schneps, Roy Gould, Gerhard Sonnet
- Project Manager: Hal Coyle
- Survey Staff: Jaimie Miller, Nancy Cook Smith, Cynthia Crockett, Marc Schwartz (McGill), Annette Trenga, Bruce Ward, Bruce Gregory
- Graduate Students: Zahra Hazari, John Loehr
- Advice
  - Elizabeth VanderPutten, Janice Earle, Joyce Evans, Barry Sloane, Larry Suter of the National Science Foundation

- Financial support
  - Smithsonian Institution, NSF, NIH, NASA Annenberg Foundation.
- Center for Astrophysics
  - Irwin Shapiro, Susan Roudebush, Judith Peritz, Charles Alcock.
<table>
<thead>
<tr>
<th>I: The Characteristics of Organisms</th>
<th>II: Life Cycles of Organisms</th>
<th>III: Organisms and Their Environments</th>
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<tbody>
<tr>
<td>I.A: Organisms need specific environments</td>
<td>II.A: Organisms have life cycles</td>
<td>III.A: All animals depend on plants</td>
</tr>
<tr>
<td>I.B: Organisms have specialized structures</td>
<td>II.B: Organisms resemble parents</td>
<td>III.B: Behavior linked to environment (includes survival or death when environment changes)</td>
</tr>
<tr>
<td>I.C: Behavior cued externally &amp; internally</td>
<td>II.C: Types of characteristics (i.e., inherited and environmentally affected)</td>
<td>III.C: Organisms alter environments</td>
</tr>
<tr>
<td></td>
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<td>III.D: Humans depend on natural and constructed environments</td>
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Multiple Topics and Levels, SMK

Effect Size

error bars=±2SE

MSP Institute

A C D H M T