Partnership to Improve Student Achievement through Real World Learning in Science, Engineering, Mathematics and Technology

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Center for Innovation in Engineering and Science Education

STEVENS
Institute of Technology
NJ Math-Science Partnership

- Stevens Institute of Technology
- Montclair State University
- Bank Street College of Education
- Liberty Science Center
- 57 Grade 3-5 teachers in 6 urban school districts in Northern New Jersey
- 555 students of MSP teachers
Goals

- Improve teachers’ content knowledge in science & engineering
- Improve teachers’ pedagogical knowledge in creating & adopting science inquiry & engineering lessons
- Improve students’ content knowledge in science & engineering (Grades 3-5)
# Focus

<table>
<thead>
<tr>
<th>Year 1:</th>
<th>Life Science</th>
<th>Environmental Science</th>
<th>2007-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 2:</td>
<td>Earth Science</td>
<td>Space Science</td>
<td>2008-09</td>
</tr>
<tr>
<td>Year 3:</td>
<td>Physical Science</td>
<td></td>
<td>2009-10</td>
</tr>
</tbody>
</table>

*Technological literacy throughout*
Program Structure

- Intensive two-week summer institute
- 3 professional development workshops during the school year
- Monthly classroom visits
- Project website and listserv
Summer Institute Content

- Science lessons with focus on scientific inquiry
- EiE curricula
- CIESE Internet-based real time data and telecollaborative projects
- Faculty presentations, lab tours, workshops & hands-on activities
EiE Modules

- Developed by the Museum of Science, Boston
- Integrate elementary science topics with a specific field of engineering
- Feature hands-on activities
- Engage students in the engineering design process
EiE Catching the Wind: Testing a Windmill
Local Geology “Rock Walk”
Science Inquiry Models

Earth tilts on its axis and this causes the seasons. The tilt causes the sun to be at different angles, affecting the amount of sunlight received at different latitudes.

- **Spring**: The sun is at a high angle, causing warm weather.
- **Summer**: The sun is at its highest, causing the sun to be directly overhead.
- **Fall**: The sun is at a lower angle, causing cooler weather.
- **Winter**: The sun is at its lowest, causing cold weather.

The tilt of the earth causes different places to have different seasons. After doing this model with a flashlight, we see how the light hits the floor at different angles in different places.
Teacher Evaluation

- Pre and post tests for treatment and comparison groups
- Questions taken from NAEP, TIMSS, MOSART & MOS (20 science and 5 engineering questions)
- Formative assessments for summer institutes
- Development and implementation of STEM learning module
- Classroom artifacts
Student Evaluation

- Pre and post tests for treatment and comparison groups
- Teacher evaluation of student work
What Causes the Seasons?
EiE Catching the Wind: Designing a Sail
Year 1 Results (Teachers)

Impact on Teacher Content Knowledge in Science and Engineering

<table>
<thead>
<tr>
<th>Assessment</th>
<th>N</th>
<th>Minimum Score</th>
<th>Maximum Score</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Test</td>
<td>57</td>
<td>12</td>
<td>24</td>
<td>20.47</td>
<td>2.682</td>
</tr>
<tr>
<td>Post-Test</td>
<td>56</td>
<td>17</td>
<td>25</td>
<td>22.38</td>
<td>1.805</td>
</tr>
</tbody>
</table>

Increase is statistically significant \( t(56) = 6.11, p<.001 \)

The mean score of teachers in the treatment group increased by 1.91 points or 7.6 percentage points.
Year 1 Results (Teachers)

Analysis of Treatment & Comparison Teachers

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Teachers</th>
<th>Mean Pre Test Score</th>
<th>Mean Post Test Score</th>
<th>Mean Score Change</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Raw Score</td>
<td>Percentage Points</td>
</tr>
<tr>
<td>Treatment</td>
<td>56</td>
<td>20.47</td>
<td>22.38</td>
<td>+1.91</td>
<td>+7.6</td>
</tr>
<tr>
<td>Comparison</td>
<td>33</td>
<td>21.12</td>
<td>21.79</td>
<td>+0.67</td>
<td>+2.7</td>
</tr>
</tbody>
</table>

Difference between the groups is statistically significant $F(1,88) = 5.973, p=.017$

The mean score of the treatment group increased by 7.6 percentage points from pre to post test while the comparison group of teachers gained only 2.7 percentage points on average.
Year 1 Results (Teachers)

“The inquiry and engineering design process are both eye-openers for me, as far as teaching is concerned.” – Nonpublic School Teacher, Evaluation Report, August 2007.

- Successful transfer of learning from the workshops to the classroom
- Increase in motivation and attitudes toward science and engineering
## Year 1 Results (Students)

### Analysis of Student Scores, Composite

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Score</th>
<th>Mean Score Change</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td>Raw Score</td>
</tr>
<tr>
<td>Treatment</td>
<td>555</td>
<td>8.34</td>
<td>11.59</td>
<td>3.25</td>
</tr>
<tr>
<td>Comparison</td>
<td>558</td>
<td>8.39</td>
<td>9.61</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Difference in gains (mean score change) is statistically significant $F(1,1112) = 112.9, p<.001$

Students of teachers in the treatment group had **gains in science and engineering content more than 2.5 times greater** than the students of teachers in the comparison group.
Year 1 Results (Students)

Analysis of Student Scores, Science

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Score</th>
<th>Mean Score Change</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td>Raw Score</td>
</tr>
<tr>
<td>Treatment</td>
<td>555</td>
<td>7.11</td>
<td>9.47</td>
<td>2.36</td>
</tr>
<tr>
<td>Comparison</td>
<td>558</td>
<td>7.11</td>
<td>8.11</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Difference in gains (mean score change) is statistically significant $F(1,1112) = 72.80, p<.001$

Students of teachers in the treatment group had science achievement gains almost 2 times greater than the students of teachers in the comparison group.
GPRA Reporting

- **Teachers**
  - No. of teachers receiving MSP PD in science: 57
  - No. of teachers with both pretest and posttest scores in science content knowledge: 56
  - No. of teachers who showed significant gains in science content knowledge: 43

- **Students**
  - No. of students taught science by MSP teachers: 555
  - No. of students with student assessment data in science: 203
  - No. of students who scored at proficient or above in science: 125
Year 1 Teacher Survey Results

- Teachers view of integrating engineering design process (EDP) in learning science:
  - EDP motivated their students to learn
  - EDP engaged them in problem solving
  - Students were constantly engaged in asking questions, discussing the activity, etc.
  - EDP fostered critical thinking skills
  - EDP is easy for students to understand and use
  - “Science is now their favorite subject.”
Year 2 Focus

- Earth & Space (Science & Engineering)
- Model-based Inquiry
- Teacher’s notion of inquiry
- Classroom observation protocol- to monitor classroom practices
Year 2 Teacher Science Inquiry Survey Results

- Almost 50% of teachers described their classroom to be “somewhat” inquiry-based.
- There was no correlation between the teachers’ years of teaching experience and their ratings of their classrooms as inquiry-based.
- Majority of teachers felt that they need to change the way they teach to make their classroom more inquiry-based.
<table>
<thead>
<tr>
<th>Activity</th>
<th>No need of change</th>
<th>Need of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working individually</td>
<td>61%</td>
<td>36%</td>
</tr>
<tr>
<td>Memorizing definitions of science terms</td>
<td>49%</td>
<td>47%</td>
</tr>
<tr>
<td>Reading textbooks</td>
<td>49%</td>
<td>47%</td>
</tr>
<tr>
<td>Working with their classmates in groups</td>
<td>49%</td>
<td>47%</td>
</tr>
<tr>
<td>Making sense of data</td>
<td>8%</td>
<td>88%</td>
</tr>
<tr>
<td>Explaining things in scientific ways</td>
<td>8%</td>
<td>86%</td>
</tr>
<tr>
<td>Planning investigations</td>
<td>10%</td>
<td>84%</td>
</tr>
<tr>
<td>Conducting investigations</td>
<td>14%</td>
<td>84%</td>
</tr>
<tr>
<td>Reflecting on their work through writing or discussion</td>
<td>14%</td>
<td>84%</td>
</tr>
<tr>
<td>Using evidence to support their conclusions</td>
<td>14%</td>
<td>84%</td>
</tr>
<tr>
<td>Explaining why something is happening in their own way</td>
<td>14%</td>
<td>82%</td>
</tr>
<tr>
<td>Working on real world problems</td>
<td>16%</td>
<td>82%</td>
</tr>
<tr>
<td>Asking questions about their results</td>
<td>16%</td>
<td>80%</td>
</tr>
<tr>
<td>Arguing from data</td>
<td>16%</td>
<td>73%</td>
</tr>
<tr>
<td>Making thinking visible through models &amp; modeling</td>
<td>22%</td>
<td>73%</td>
</tr>
</tbody>
</table>
Teachers’ Impediments to Ideal Science Teaching

- Student Population
  - Students of different ability-levels
  - Behavioral & discipline problems
  - Not used to scientific inquiry
  - Lack of collaborative working skills
  - Special education needs
  - Class size
  - Lack of parental support
- Time & test prep issues
- Resources
- Curriculum-related challenges
- Policy and/or Leadership expectations
Samples of Student Work in Model-based Inquiry

Reasons for Seasons – 3rd Grade
Level 0- No, little, or incorrect understanding

2. In the box, draw what you think causes these seasons.

Naïve Model - Student E

3. Why do you think we have seasons? Explain.
I think we have seasons because we live one as different context and if you go somewhere else it might be a different climate.

4. How do you know that?
I looked it up on the computer.
Level 1 - Some understanding. The student can make a diagram/representation but can't explain or has incorrect explanation.

2. In the box, draw what you think causes these seasons.

The Winter

The Summer is what makes the season

The Spring makes the season

The Fall

1st Revised Model- Student C
Level 2- Better understanding. Student can identify the parts of the model but can't make connections (diagram/representation and explanation)

2. In the box, draw what you think causes these seasons.

If the earth was flat we will have always have Spring and Fall
If the earth was slanted we will have Winter, Spring, Summer, and Fall

3. Why do you think we have seasons? Explain.
The tilt makes the seasons.

4. How do you know that?
When the earth is flat we will have always Spring and Fall. When the earth is slanted we will have Winter, Spring, Summer, Fall.
Level 3- Accepted Model & Explanation

2. In the box, draw what you think causes these seasons.

```
The reason for the seasons is how the earth tilts. If the earth was straight it would always be fall or spring.
earth tilted
```

3. Why do you think we have seasons? Explain.

```
I think we have seasons because the sun and earth tilted think that because when the sun is fading the months become winter.
```

4. How do you know that?

```
I learned that when someone taught me.
```
Model-based Inquiry Results

- Beginning of the lesson
  - 27 students are at Level 0
  - 2 students are at Level 1

- After the first lesson
  - 7 students remained at Level 0
  - 19 students moved from Level 0 to 1
  - 1 moved from Level 0 to 2
  - 1 moved from Level 0 to 3
  - 2 students remained at Level 1
For More Information

Overview

A partnership of 80 teachers from 24 schools from the districts of Becton, Belleville, Haskell, Jersey City, Newark, Palisades Park, West Orange, and two non-public schools, together with Stevens Institute of Technology, Montclair State University, and Liberty Science Center, will provide teams of teachers with deeper science content knowledge, research-based professional development, and experience with innovative science and engineering curricula and materials for Grades 3-5. The Boston Museum of Science’s National Center for Technological Literacy and Kent State College of Education are also partners in this collaboration. Teachers will participate in a dynamic and supportive learning community designed to address topics in key content areas in Grades 3-5 science, engineering, and technology education. Year 1 activities will focus on New Jersey Core Curriculum Content Standards 4.5 and 5.10 (life and environmental sciences) and 5.2 (technology education).

An intensive, two-week summer institute will involve teachers in collaborative learning through engagement in science inquiry, engineering design, foundational learning in core science topics, and the development of a Science Technology/Engineering Mathematics Learning Module (STEM Learning Module) that introduces topics in science through inquiry-based activities and use of the engineering design process. Teams will work together on developing the module, including identification of student science learning objectives (that echo the district science curriculum and the NJCCCS) lesson plans, implementation and classroom management plans, and student assessments.

These professional development days during the school year and monthly classroom visits will support teachers as they implement content and materials during the school year.

Assessment of student and teacher learning will take place within participating classrooms and in comparison classrooms.

www.stevens.edu/ciese/pisa
Disclaimer

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