The Role of PER in Introductory Course Reform and Physics Teacher Preparation

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SPIN-UP workshop
June 5th, 2010
What is Physics Education Research (PER)?

What is unique about Rutgers PER?

What does Rutgers PER do?

PER study #1

PER study #2

PER and preparation of Physics Teachers at Rutgers
What is Physics Education Research?

PER uses the tools and methods of science to study and improve the teaching and learning of physics.

(J. Redish)
What is Physics Education Research?

PER uses the tools and methods of science to study and improve the teaching and learning of physics.

Interdisciplinary:

- Physics
- Education research
- Brain research, linguistics, sociology, etc.
What is unique about Rutgers PER?
QuickTime™ and a decompressor are needed to see this picture.
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Work of Rutgers PER

Curriculum Development and Tool Development

Research in Reformed courses

Rutgers Astrophysics Institute

Introductory Course Reforms

Physics Teacher Preparation

Pure PER Research
Example of Course Reforms (Pioneering work of late G. Horton)

- Underrepresented students on the path to engineering

George Horton

Suzanne Brahmia

Extended Analytical Physics
Extended Analytical Physics (EAP) I
3 credits per semester

Analytical Physics (AP I)
2 credits per semester

Analytical Physics II (AP II)
3 credits per semester

Parallel-path Model
Retention in STEM Majors

% of 1st-yr students

Before ('85&'86)  After ('92&'93)  Current ('01&'02)

- All
- Women
- URM
Other Course Reforms, Outreach, and Research Combined

- Thinking like a scientist (both undergrads and high school students including research in X-ray astrophysics!)
Reformed courses as PER research laboratory

- Multiple representations and student problem solving
- Development of self-evaluation skills
- Ability to solve multiple possibility problems
Pure Research

Language and student learning of physics

New paradigms in transfer research
Research tools that we use

- Direct observations
- Videotaping, transcribing, and coding
- Interviewing (think aloud protocols)
- Scoring written work using rubrics
- Coding exam work
- Pre instruction - post instruction testing
- Surveying
What do we do for the physics department?

• Develop curriculum materials
• Push and sustain courses reforms
• Advise grad students who are working on a physics PhD in PER
• Educate TAs
• Take care of graduates
• Run Rutgers Astrophysics Institute
• Help with NSF educational outreach component on proposals
What do we do for the school of education?

Maintain one of the biggest physics teacher preparation programs in the country!

6-8 graduates per year!
Physics for the Sciences (193-194) is our laboratory.
Physics for the Sciences - algebra based (almost no pre-meds)
200/year

What should their education focus on?
(Education is what one remembers when everything is forgotten).
They will encounter most physics content in the course ONCE but if we focus on the process then there are MULTIPLE opportunities to see the same process again and again.

Can we use physics as a context to help students develop “physics habits of mind”?
Investigative Science Learning Environment (ISLE)
Etkina and Van Heuvelen, 2001

Observational experiments

Pattern

Explanation, mechanism, hypothesis, relation

Prediction

Assumptions

Testing experiments

Yes

More

Application

Revision

more

different

assessment

+
ISLE-based courses

Physics for the Sciences 193-194
Extended Analytical Physics 114-115
Total of 350 students/year
Some of the main goals of ISLE are to help students understand how knowledge is constructed and develop scientific habits of mind.

What are those?

We call them SCIENTIFIC ABILITIES.
What are scientific abilities?

9 people + a lot of history

representing physical processes and ideas

designing an experimental investigation

collecting and analyzing data

devising and testing a qualitative explanation or a quantitative relation

modifying an explanation or a relation in light of new data

evaluating

communicating
### Rubrics for guidelines, assessment and self-assessment

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>ABILITY</th>
<th>Missing (0)</th>
<th>Not adequate (1)</th>
<th>Needs improvement (2)</th>
<th>Adequate (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To evaluate specifically the ways in which the assumptions might affect the result</td>
<td>No attempt to determine the effects of relevant assumptions.</td>
<td>An attempt is made but effects are described vaguely.</td>
<td>The effects of relevant assumptions are determined correctly but assumptions are not validated.</td>
<td>The effects of relevant assumptions are determined and assumptions are validated.</td>
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To evaluate specifically the ways in which the assumptions might affect the result:

- **Missing (0)**: No attempt to determine the effects of relevant assumptions.
- **Not adequate (1)**: An attempt is made but effects are described vaguely.
- **Needs improvement (2)**: The effects of relevant assumptions are determined correctly but assumptions are not validated.
- **Adequate (3)**: The effects of relevant assumptions are determined and assumptions are validated.
One approach (we use many more): The lab is completely integrated and basically drives the course.

In the labs students do initial observations to come up with patterns or models, and then they test and apply them after a discussion in a large room meeting. THEY DO NOT READ THE BOOK BEFORE CLASS!

Recitations are dedicated to analyzing processes using multiple representations (problem solving but not traditional)
Students design their own experiments in every lab!

Design an experiment to find a relation between a voltage across and current through a commercial resistor. Design an experiment to test whether this relation applies to an incandescent light bulb.

Design an experiment to test a hypothesis: interaction of electrically charged objects can be explained by magnetism.

Design two independent experiments to determine the specific heat of the given object. The material of the object is not known.

Use the list of available equipment (xx, xx) to pose your own question. Investigate the question and write a report.
Scientific Abilities

Group Members
Members of the Rutgers University Physics and Astronomy Education Research (PAER) group.

Introduction to Scientific Abilities
An introduction to scientific abilities.

The Abilities
The scientific abilities.

Rubrics
The scientific abilities self-assessment rubrics. (Revised 02/18/2008)

Formative Assessment Tasks
Formative Assessment Tasks.

Design Experiments
Design Experiments.

Kits
Kits

Modeling Tasks
Modeling Tasks

http://paer.rutgers.edu/scientificabilities/
### Physics Teaching Technology Resource

<table>
<thead>
<tr>
<th>Users</th>
<th>Introduction</th>
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<tbody>
<tr>
<td>Log in</td>
<td>This is a long introduction for physics teachers and those interested in Prof.</td>
</tr>
<tr>
<td>Forgot your password?</td>
<td>Etkina's teaching methods.</td>
</tr>
<tr>
<td>Sign me up</td>
<td></td>
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<tr>
<td>Why sign up?</td>
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<table>
<thead>
<tr>
<th>Information</th>
<th>Motion</th>
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<tbody>
<tr>
<td>About us</td>
<td>Learning cycles on the subject of Kinematics.</td>
</tr>
<tr>
<td>FAQ</td>
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<thead>
<tr>
<th>Essential Links</th>
<th>Newton</th>
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<tbody>
<tr>
<td>ISLE Physics Network</td>
<td>Learning cycles on Newton's Laws</td>
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<td>Scientific Abilities</td>
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<td>Compadre</td>
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<tr>
<th>PIRA</th>
<th>Circular and Rotational Motion</th>
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<tbody>
<tr>
<td></td>
<td>Learning cycles on circular and motion and motion with rotation in it</td>
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<th>Energy</th>
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<td></td>
<td>Learning cycles on work and energy.</td>
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Scientific abilities study

Physics for the sciences 193/194 (190 students)

Introduced ISLE and design labs in 2003

Scored lab reports $(60 \times 14 \times 3 \times 3) = 8000$ pages of student work

Used rubrics

Reliability $> 90\%$
Ability to identify uncertainties

Lab 8
Lab 7
Lab 5#2
Lab 5#1
Lab 4#2
Lab 4#1
Lab 2

0&1
2&3
Ability to evaluate uncertainties estimating the largest uncertainty
Ability to identify assumptions

- Lab3
- Lab4#1
- Lab4#2
- Lab5#1
- Lab5#2
- Lab7
- Lab8
- Lab9
Ability to evaluate assumptions

![Bar chart showing ability to evaluate assumptions for various lab sessions. The chart uses two colors: light gray for 0&1 and dark gray for 2&3. Each lab session is represented by a horizontal bar with a percentage bar chart indicating the distribution between 0&1 and 2&3.]
Research on scientific abilities

200 students in two courses over 3 years

Found

Time dependence

Content dependence (especially the effects of assumptions!)

Significant improvement

Saturation
Transfer project

Experimental and control group
Same course

Experimental group
Design labs + Rubrics

Control group
PER based labs non-design

Comparison

- Designing a physics experiment
- Designing a biology experiment
- Solving regular exam problems

Week 1-10

Week 12

Week 13

Week 5, 11, 15
Time Spent on the lab activities
Weeks 1 through 10
Physics transfer task:
Investigation of the behavior of the balloon

Design experiments to determine whether the helium balloon and the air balloon have the same drag coefficients.
Time spent on lab activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Design</th>
<th>Non-design</th>
<th>p - level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time</td>
<td>162±17min</td>
<td>120±25min</td>
<td>0.0375</td>
</tr>
<tr>
<td>Sense-making</td>
<td>52±10min</td>
<td>15±5min</td>
<td>0.0007</td>
</tr>
</tbody>
</table>
Scientific Abilities

Ability to identify the assumptions

- Difference is statistically significant
  - Chi-square = 67.90, $p < 0.001$
  - Identified relevant and significant assumptions
    - 64% of design students
    - 13% of non-design students

Ability to evaluate/validate effect of assumptions

- Difference is statistically significant
  - Chi-square = 53.3, $p < 0.001$
  - “0” – missing
  - “1” – inadequate
  - “2” – needs some improvement
  - “3” – adequate
Scientific Abilities

Ability to evaluate the uncertainty

Difference is statistically significant
Chi-square = 30.1167, $p<0.001$

Ability to evaluate the results by independent method

Difference is statistically significant
Chi-square = 16.36, $p < 0.001$

“0” – missing
“1” – inadequate
“2” – needs some improvement
“3” – adequate
Physics understanding

Free Body Diagram

Consistency of multiple representations

Difference is statistically significant
Chi-square = 17.73, p<0.001

2% of design students
22% of non-design students have score “1” - draw wrong FBD

Difference is statistically significant
Chi-square = 7.838, p<0.025

“0” – missing
“1” – inadequate
“2” – needs some improvement
“3” – adequate

Design
Non-design
Conduct two experiments to determine transpiration rate using stem cuttings from a single species of plant.
Summary of findings

Time on sense making
Professionalism in lab reports
Coordinated representations
Recognized assumptions
Evaluated uncertainties
Results, evaluated by an independent method
Preparation of high school physics teachers

Ed.M. with certification in physical science
(5 year program and a post bacc)
Over 40 graduates in 7 years are now teaching (without a penny of external or internal funding)
Physics Teacher Preparation is GSE-based

- Helps with recruitment
- Allows flexibility
- Provides with opportunities for teaching in reformed courses
- Provides teaching role models
- Provides access to equipment and connects to NJAAPT
Ed.M. with certification in physical science

**FIVE** 3-credit courses in how to teach physics

+ Students teach labs and recitations in 193/194 practicing working with students in a new way before they do student teaching in the schools.

This teaching is integrated in their course work in the GSE
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Thank you!