From research to practice: Why hasn’t educational research had more of an influence on teachers and what can we do about it?

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Western Michigan University
http://homepages.wmich.edu/~chenders/

Main Point

The current situation
Physics Education Research (PER)-based curricula and research results are not used as much as they should be.

An important problem
PER dissemination activities are not usually connected to any explicit model or theory of change.
  • makes it difficult to plan and coordinate effective dissemination activities
  • inhibits the development and testing of theory
Overview

1. The current situation
   a) PER research and development (brief)
   b) PER dissemination activities (brief)
   c) How much of an impact have #1 and #2 had?

2. Change Models/Strategies
   a) Your models/strategies
   b) Tools for thinking about change models/strategies
   c) Expanding models/strategies

Focus of this workshop is on change in college-level physics instruction. The issues in K-12 are not so different.

What physics education research has done...

Identified many problems with traditional methods of instruction.

- Ineffective at developing understanding of physics concepts, problem-solving skills, and understanding of the processes of science
- Students often develop negative attitudes towards science.
- High attrition rates, especially for women and racial minorities.
Found Solutions!
Replace lecture with hands-on, inquiry based activities.
Encourage and support cooperative learning.
Explicitly teach problem solving.

Traditional Physics class at University of Rochester
SCALE-UP Physics class at Clemson University

Technology

Classroom Response Systems

Java Applets
Research-Based Nationally-Normed Assessments

From: http://www.ncsu.edu/per/TestInfo.html
Research-Based Materials

More Research-Based Materials

UMN Online archive of context-rich problems:
http://groups.physics.umn.edu/physed
Evidence that Research-Based Reform Works!

Student learning gains on the Force Concept Inventory

PER Dissemination Activities

1. Talks
   a) Departmental Colloquia
   b) Professional Meetings (AAPT, APS, AAS)
2. Workshops
   a) Single-day (e.g., AAPT Workshops)
   b) Multi-day (e.g., New Faculty Workshop)
   c) 1-2 Weeks in summer (e.g., Workshop Physics)
3. Papers
   a) Specific articles (e.g., focused on a particular method)
   b) General articles (e.g., on learning theory, misconceptions, etc.)
4. Books
   a) Already discussed (often available for free from textbook publishers)
General Features of Dissemination

1. Aimed at changing individual instructors.
2. Transmission-oriented with four main segments:
   1. Problems with traditional instruction are identified and described
   2. An instructional strategy is introduced that can overcome these problems
   3. Evidence is presented to show that the new strategy is successful
   4. The presenter attempts to motivate the audience to try (e.g., it’s not so hard…)

What Impact has PER dissemination activities had on Instruction?

Limited Data Exists

- **Peer Instruction:**
  - 353 self-described users of Peer Instruction. “Most” teach physics.

- **Just-in-Time Teaching (JiTT)**
  - 71 United States physics instructors who use JiTT for introductory physics.

- There are ~11,360 physics faculty employed in two-year and four-year colleges in the United States.
  - Peer Instruction – 3.1% of faculty
  - JiTT – 0.6% of faculty

Experts Consider Use of PER to Be Low

“Most introductory [science] courses rely on transmission-of-information lectures and cookbook laboratory exercises.”

http://scientificteaching.wisc.edu/ScientificTeaching/ScientificTeaching.pdf

In a web survey of 30 PER practitioners, 80% agreed or strongly agreed that “Physics faculty teach very traditionally.”


“A crucial question, then, is why introductory science courses in many colleges and universities still rely primarily on lectures and recipe-based laboratory sessions.”


The Dissemination Activities Commonly Used by PER have yet to prove their effectiveness

One Problem:

“In reform efforts, the theory or theories that underwrite the chosen forms of actions often remain unstated.”*

*E. Seymour, “Tracking the process of change in us undergraduate education in science, mathematics, engineering, and technology,” Science Education. 86, 79-105 (2001), p. 90.
Why Reform Models are Important

Changing reform models of the Foundation Coalition*

Foundation Coalition:

• What: 6 institutions to develop and implement a new 4-year engineering curriculum
• When: First grant – 1993-1998 ($14M)

Elicitation Activity

What is your current model of reform?

Assuming that a goal of educational reform is to have a majority of physics faculty teach in a manner consistent with the general recommendations of PER, how do we get there?

Describe an activity or set of activities that can lead to reform. Be explicit about how the activities lead to the goal.

(If thinking about reform at the national level seems too big, perhaps consider just your institution or department.)

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Group Discussion
Group Consensus Model of Reform

- Groups of 4-5
- Sit with people you do not know well and who are not from your institution

1. Introductions
2. Share Individual Models
3. Create Group Model

Your Task: Assuming that a goal of educational reform is to have a majority of physics faculty teach in a manner consistent with the general recommendations of PER, how do we get there?

Describe an activity or set of activities that can lead to reform. Be explicit about how the activities lead to the goal.

Tools for thinking about change activities and change models
Tool 1: Three Foci of Change Activities

- **Curriculum**
  - Conduct research and develop curricular materials and strategies
  - Disseminate these to other faculty

- **Teachers**
  - Motivate/empower individual teachers or small groups to focus on instructional improvement

- **Structures**
  - Study how institutional structures influence teacher practices and student learning

Three Foci

Most change strategies only focus on one area

Emphasizing only one of these areas is not likely to lead to widespread reform, but it can have some local impact – there is a lot known about “best practices” within each area.
Common Strategies for Each Foci

Important parts of the System

(focus on curriculum)

Bottom-Up Change Models

- Funding Agencies
- Science Education Researchers
- Faculty
- Department
- Institution
- Funding Agencies
- Science Education Researchers
- Higher Education Researchers

**Funding Agencies**
- Funding for specific curriculum development projects
- Strong Evidence

**Science Education Researchers**
- Curriculum developers conduct research and develop/test innovations

**Faculty**
- Innovation spreads to other faculty and continues to spread
- Little or No Evidence

**Department**
- Once enough faculty use innovation it begins to influence other parts of the system

**Institution**
- Center for T&L

[Diagram of a system showing the flow of innovation from funding agencies to faculty to the institution]
A more modest agenda: Getting innovations used by other faculty

This typically involves dissemination to individual faculty.

Dissemination to Individual Faculty

<table>
<thead>
<tr>
<th>Activity</th>
<th>Problem</th>
<th>Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify problems with traditional instruction</td>
<td>Many faculty are already dissatisfied</td>
<td>Can be insulting and lead to defensiveness May not be necessary</td>
</tr>
<tr>
<td>2. Describe an instructional strategy that can overcome these problems</td>
<td>Supply information about only 1 curricula Not always explicit about critical pieces</td>
<td>Can be insulting and lead to defensiveness “they think their way is the only way” Instructors may not understand principles of curricula</td>
</tr>
<tr>
<td>3. Present evidence that the new strategy is successful</td>
<td></td>
<td>Instructors are not often persuaded by such evidence</td>
</tr>
<tr>
<td>4. Motivate audience to try (e.g., it’s not so hard…)</td>
<td>Ignores resistive situational factors Implementation success often requires significant implicit knowledge</td>
<td>Innovations may be given up after a brief trial (after situational factors are realized) Innovations typically not implemented with “fidelity”</td>
</tr>
</tbody>
</table>
Dissemination to Individual Faculty

Think individually, then discuss with group.

1. Do these problems and realities fit with your experiences?
2. Are there other problems/realities that you would include?

Tool 2: What types of Changes do we Expect?

Adoption-Invention Continuum:
Possible Relationships Between PER and Faculty

<table>
<thead>
<tr>
<th>Adoption</th>
<th>Adaptation</th>
<th>Reinvention</th>
<th>Invention</th>
</tr>
</thead>
<tbody>
<tr>
<td>The change agent</td>
<td>The change agent</td>
<td>Instructor uses the</td>
<td>The instructor develops</td>
</tr>
<tr>
<td>develops all of</td>
<td>develops the materials and procedures and</td>
<td>ideas of the change agent but</td>
<td>materials and procedures that</td>
</tr>
<tr>
<td>the materials and</td>
<td>gives them to the instructor who</td>
<td>significantly alters</td>
<td>are fundamentally based on his/her</td>
</tr>
<tr>
<td>procedures and</td>
<td>changes them</td>
<td>them or develops</td>
<td>own ideas.</td>
</tr>
<tr>
<td>gives them to the</td>
<td>slightly before</td>
<td>fundamentally new</td>
<td></td>
</tr>
<tr>
<td>instructor to</td>
<td>implementing.</td>
<td>procedures based on</td>
<td></td>
</tr>
<tr>
<td>implement as is.</td>
<td></td>
<td>the change agent</td>
<td></td>
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</tbody>
</table>


Adoption-Invention Continuum: Possible Relationships Between PER and Faculty

Invention

Adoption

Adoption-Invention Continuum: Possible Relationships Between PER and Faculty

Implement

Develop Details

Develop Essential Features

Develop Basic Idea

Adoption

Adaptation

Reinvention

Invention

Example – Peer Instruction (Mazur, 1997)

Basic Idea: Students are asked to respond to short conceptual questions during lecture to increase engagement and provide feedback to the instructor.

Essential Features:
- Reading assignment or quiz before lecture.
- Conceptual tests (CTs) are used to segment lecture.
- Peer-peer discussion of CTs.
- Conceptual questions on exams.

Details:
- Specific concept tests, reading quizzes, and exam questions
- Timing: 5-7 min lecture, CT, ~2 min discussion, CT
- Flash card or PRS system for managing student responses
- CTs characteristics: focus on common student difficulties, 35%-70% of students should initially answer incorrectly
- Coverage is same, but not all material is presented in class
Example – Peer Instruction

**Adoption:** Use “as is”
- Take Mazur’s book, follow recommendations and use available materials.

**Adaptation:** Change some details to suit individual situation
- Instead of multiple choice CTs, use free response questions.

**Reinvention:** Take basic idea, but drastically change or eliminate at least one essential feature
- Have one CT at end of class
- Eliminate student-student discussion

**Invention:** Do something completely different

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Using the Adoption-Invention Continuum: An Example*

**Open-Ended Interviews**
- Five instructors, four institutions
- Tenured
- No formal connections with PER
- Thoughtful, reflective, well-respected

This type of instructor is highly likely to be interested in educational research


Faculty aware of Problems and Solutions

PER and faculty agree on many problems
  • e.g., All five faculty stated (without prompting) that traditional lecture is largely ineffective.

Faculty aware of many possible solutions
  • Knew names and basic practices of many PER curricula.

PER and Faculty Agree on Many Problems

<table>
<thead>
<tr>
<th>Instructional Problem</th>
<th>Instructors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students don't get much from traditional lecture.</td>
<td>T  H  M  G  B</td>
</tr>
<tr>
<td>Different kinds of students learn differently.</td>
<td></td>
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<tr>
<td>Students have misconceptions that are not simple to change.</td>
<td></td>
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<tr>
<td>Many students have poor problem solving skills</td>
<td></td>
</tr>
<tr>
<td>Assessment difficulties – getting the right answer does not mean that a student understands</td>
<td></td>
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<tr>
<td>It is helpful to tailor explanations to individual students, but this is difficult/impossible in a large class</td>
<td></td>
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<tr>
<td>Students have great difficulty learning the basic concepts of physics</td>
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</tbody>
</table>
### Faculty Aware of PER Solutions

<table>
<thead>
<tr>
<th>Potential Solution</th>
<th>Details</th>
<th>Existence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer Instruction</td>
<td>![Symbol]</td>
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<tr>
<td>Physlets</td>
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<tr>
<td>CUPS/CUPLE</td>
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<td>Washington Tutorials</td>
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<td>Workshop Physics</td>
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<tr>
<td>Real-Time Physics and Interactive Lecture Demonstrations</td>
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<tr>
<td>&quot;Army&quot; method. Pose question, pause, call on student.</td>
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<tr>
<td>Have students write down answer after posing a question.</td>
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<tr>
<td>Discussion-based teaching techniques</td>
<td>![Symbol]</td>
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<td>FCI/CSEM as an assessment instrument</td>
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<td>Modeling/discussing expert thinking related to problem solving</td>
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<tr>
<td>Individual interviews with each student – motivational</td>
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<tr>
<td>White boards to encourage students to interact during class.</td>
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<tr>
<td>Problem solving framework.</td>
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<tr>
<td>Small group work</td>
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<tr>
<td>Physics by Inquiry</td>
<td>![Symbol]</td>
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<td>Scale-UP</td>
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<tr>
<td>Matter and Interactions</td>
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<td>Personal response systems</td>
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### Faculty Engage in Reinvention

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<tr>
<td>&quot;Exercises&quot; to guide students through solving a problem</td>
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<tr>
<td>Different instruction for different student abilities</td>
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<tr>
<td>Solicits questions from students</td>
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<tr>
<td>Lecture-based questions</td>
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Why Reinvention?

Faculty do not believe an externally developed curricula can match their unique style, preferences, skills, and teaching situation

- “Many [PER Curricula] don’t transport very well out of the environment in which they were developed because they were developed for certain set of teachers in a certain educational environment with a certain set of students.” (Terry)
- “I mean a lot of things I won’t even bother trying because I know I’m not the right person to do it.” (Harry)

PER Expects Adoption/Adaptation

From 2005 NSF-CCLI Solicitation
Divergent Expectations → Problems

From Faculty Perspective

• Each PER practitioner is selling a particular curricula and not interested in them or their students

• PER does not recognize/value faculty skill and experience

From PER Perspective

• Faculty are not interested in our work and, thus, must not care about teaching

• Faculty inappropriately modify our curricula

What do Faculty Want?

PER and faculty work together

• “I've spent my life doing this [teaching] and part of my teaching is in fact to be aware of all of the things that are going on, but I want it to be useful and meaningful to that discourse.” (Terry)

PER to develop more theory than packaged curricula

• “I have a good feel for the conditions under which [optical phenomena] occurs . . . I don't have an intellectual framework around which to organize innovations in teaching. . . . If I had a framework like that then I could answer my own questions [about teaching].” (Harry)

PER to communicate openly/honestly

• “It's really frustrating if somebody just falls behind a smokescreen and will start using jargon and will start talking about papers that you don’t know what’s in the paper.” (Mary)
Summary – Some Incorrect Assumptions

About faculty:
• These faculty were aware of many problem with traditional instruction and many of the available PER instructional strategies.

About the change process:
• Change agents operate with adoption/adaptation in mind, but these faculty operated with reinvention/invention in mind
• Divergent expectations contributed to the lack of meaningful change in many cases

(focus on teachers)
Faculty-Directed Change Models

Interventions can be effective when they are*:
1. Collegial
2. Exist over an extended time
3. Focus on specific goals

No Evidence that this strategy can promote widespread change

*Emerson & Mosteller, 2000
**Top-Down Planned Change Models**

Change institutional reward system to reward faculty for developing and using innovative instruction. Faculty change behavior because of this change in reward system.

**Restrictive Structures**

Institutions are set up for traditional instruction.

- Physical Infrastructure
- Departmental Norms

**Significant evidence that institutional structures can prevent change, but no evidence that changing structures alone is enough to cause change.**

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Restrictive Structures

Content Coverage Expectations

<table>
<thead>
<tr>
<th>Common 1st Semester Introductory Physics Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Vectors</td>
</tr>
<tr>
<td>3. Motion in One Dimension</td>
</tr>
<tr>
<td>7. Systems of Particles</td>
</tr>
<tr>
<td>8. Conservation of Momentum</td>
</tr>
<tr>
<td>9. Rotation</td>
</tr>
</tbody>
</table>

Student Expectations (the hidden contract)

(focus on structures)

Top-Down Planned Change Models

Problem:
Assumption of rational decision-making

“The individual’s choice to change is not often made based on a review of fact-based data; instead, people are found to consider the implication of the change on the future of the division (political), or based on intuition, or how this change relates to emotional commitments they have made.” (Kezar, 2001, p. 122)

Change models based on rational decision-making that work in business settings may not work well in academic settings due to the unique characteristics of higher education (e.g., disciplinary cultures outside institutions, outputs are ambiguously defined and difficult to measure). (Kezar, 2001)

### Strengths and Weaknesses

<table>
<thead>
<tr>
<th>Structures</th>
<th>Teachers</th>
<th>Curriculum</th>
</tr>
</thead>
</table>
| **Strengths** | -Treats faculty as professionals  
-Customization of curricula is typically necessary  
-Much implicit knowledge is used in teaching and is difficult to transmit  
-Traditional structures are barriers to change  
-Structural change is probably needed for lasting impact  
-Faculty working in isolation may reinvent the wheel  
-Traditional structures do not reward faculty for a focus on teaching  
-Faculty may subvert structural changes  
-External structures (e.g., disciplinary cultures) strongly shape faculty work | -Developing good curricula is beyond the skills and available time of most faculty  
-Faculty may use curricula inappropriately (or not at all)  
-Most effective curricula conflict with traditional structures | -Treats faculty as professionals  
-Customization of curricula is typically necessary  
-Much implicit knowledge is used in teaching and is difficult to transmit |
| **Weaknesses** | -Faculty working in isolation may reinvent the wheel  
-Traditional structures do not reward faculty for a focus on teaching | -Developing good curricula is beyond the skills and available time of most faculty  
-Faculty may use curricula inappropriately (or not at all)  
-Most effective curricula conflict with traditional structures | -Treats faculty as professionals  
-Customization of curricula is typically necessary  
-Much implicit knowledge is used in teaching and is difficult to transmit |

#### Think individually, then discuss with group.

1. Do these strengths and weaknesses fit with your experiences?
2. Are there other strengths and weaknesses that you would include?
Conclusion

An appropriate change strategy should address all three aspects.

It should be explicit about:

• Which aspects are currently aligned with the proposed change and which will provide barriers.
• How to eliminate or work around the barriers.

Many change strategies focus on only one aspect and do not consider the others.

A Promising Approach: Promote Teacher Customization

Explicitly accept current structural constraints, but provide teachers assistance in customizing research-based techniques to their own unique situations.

Examples:

• Weizmann Institute (Israel) – Ongoing teacher workshops focused on promoting student self-monitoring in problem solving
• University of Maryland – Open-source tutorials integrated with professional development materials
  http://www2.physics.umd.edu/~elby/CCLI/index.html
Another Promising Approach: Co-Teaching

An experienced teacher structures a course and teaches it jointly with a novice teacher. Novice teacher develops significant implicit knowledge about how to work effectively within the current structural constraints using a particular instructional style.

Examples:
*Western Michigan University*
- Beach, A., Henderson, C., and Famiano, M. (Accepted) “Co-Teaching as a Faculty Development Model”, To Improve the Academy.

Another Promising Approach: Department-Level Structural Change

Change departmental structures and curriculum. Ensure that changes do not conflict deeply with faculty or disciplinary beliefs and that it is easier for faculty to go along with changes than to teach traditionally.

Example:
*University of Illinois, Urbana-Champaign – Recreating university physics to align with educational research*

Revisiting Change Models

Revisit your group change model

1. Where does it fit on Tool 1: Adoption-Invention Continuum?
2. How many of the three foci (i.e., Tool 2) does it address?
3. How can your model be modified to focus on at least 2 of the three foci while explicitly accepting the third? Is it possible for a model to focus on changing all three?

The End