Barriers to Instructional Change

*Action research and professional development in math, science and technology education*

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**What’s the problem?**

- Good research and development is only valuable if it is actually used.
- Products of physics education appear to be only marginally incorporated in most physics classrooms.
- Why is research-based reform so slow and difficult?

**Overview**

- Critique of PER Change Strategy – Curriculum Development & Dissemination
- Framework for Thinking about Change Strategies
- Co-Teaching – Example of a Potentially Productive Change Strategy

**General Features of PER Dissemination**

*Talks – Papers – Workshops – Books*

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

**An Example**

*Significant Materials Available*

- 253 page book with detailed implementation recommendations and disk with ready-to-go materials:
  - In-class questions
  - Reading quizzes
  - Exam questions

- Publisher has distributed book for free to large numbers of US physics faculty.
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.”

- In a web survey of 30 PER practitioners, 80% agreed or strongly agreed that “Physics faculty teach very traditionally.”
  - http://homepages.wmich.edu/~chenders/Publications/FFPER05Poster.pdf

- “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.

Summary (so far)

- PER change models
  - Are implicit
  - Assume change will occur through curriculum development and dissemination
  - Have had minimal impact

PER Development and Dissemination

Two Major Problems

Often Ignores Environmental Characteristics

- Environments typically favor traditional instruction.
- (It is assumed that if the developer can overcome environmental barriers, so can other instructors.)

Often Ignores Teacher Characteristics

- Instructors are given no meaningful role in the change process.

One Reason: Restrictive Environments
Institutions are set up for traditional instruction

Restrictive Environments
Content Coverage Expectations
Common 1st Semester Introductory Physics Topics
1. Vectors
2. Units
3. Motion in One Dimension
4. Motion in Two Dimensions
5. Work and Energy
6. Work and Energy
7. Systems of Forces
8. Conservation of Momentum
9. Rotation
10. Static Equilibrium
11. Gravity
12. Ideal Properties of Solids
13. Mechanics of Fluids
14. Heat and Chemical Changes
15. First Law of Thermodynamics
16. Second Law of Thermodynamics
17. Oscillations
18. Waves on a String
19. Sound

When Instructors Do Make Changes They Typically Make Minimal Use Of Available Resources

Adoption-Invention Continuum: Possible Relationships Between PER and Faculty
Experts have all the important knowledge
Teachers have all the important knowledge

Faculty Engage in Invention and Reinvention
- 20 self-reported instructional changes (by 5 faculty): 70% were categorized invention or reinvention*
- 192 self-reported users of Peer Instruction: 81% report instructional activities inconsistent with essential features Peer Instruction**

Why Reinvention?
- Faculty want their knowledge and skills valued
  - "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)
  - "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)
- 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)

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PER Expects Adoption/Adaptation

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

Summary – So Far
- PER Change agents expect to disseminate reformed curricula to faculty who will follow adoption/adaptation mode.
- Faculty don’t use these curricula much and, when they do, often make significant changes:
  - Faculty cite environmental characteristics that make it difficult for them to use these new curricula
    → PER needs to pay more attention to environments
  - Faculty want their knowledge and experience to be valued during interactions with the PER community
    → PER needs to do a better job of involving faculty in the change process

What Can we Learn from Other Groups? Three Groups Focused on Change in Undergraduate STEM Instruction
- Disciplinary STEM Education Researchers (SER): Housed in the science disciplines in College of Arts and Sciences
- Faculty Development Researchers (FDR): Housed in Center for Teaching and Learning (if at all)
- Higher Education Researchers (HER): Housed in College of Education or Administration

Each group has their own professional societies, conferences, journals, etc.

Three Recent Literature Reviews

Three Groups - One Common Goal
Transform undergraduate education from the instruction paradigm to the learning paradigm.

Each group has their own professional societies, conferences, journals, etc.
Three Groups – No Communication

<table>
<thead>
<tr>
<th>Field</th>
<th>Article</th>
<th>Number of References</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SER]</td>
<td>Seymour (2001)</td>
<td>77</td>
</tr>
<tr>
<td>[FDR]</td>
<td>Emerson &amp; Mosteller (2000)</td>
<td>34</td>
</tr>
</tbody>
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No overlap in references → No communication between groups

A Larger Literature Review: Preliminary Results*

- Process:
  - Review literature related to promoting change in instructional practices used in undergraduate STEM
  - Focus on Journal articles published since 1995
  - Fall 2007: ~250 relevant journal articles identified
  - Spring 2008: categorization and analysis of articles
  - March 2008: preliminary categorization and analysis based on 75 articles (randomly selected from the 250)

*Categorized along two Important Dimensions

- What is the primary aspect of the system that the change approach seeks to directly impact?
- To what extent is the intended outcome for the individual or environment known in advance?

<table>
<thead>
<tr>
<th>Individuals</th>
<th>Environments</th>
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<tbody>
<tr>
<td>Implicit Assumption: Individuals’ actions primarily influenced by their own volition</td>
<td>Implicit Assumption: Individuals’ actions are primarily influenced by external environments</td>
</tr>
<tr>
<td>To what extent is the intended outcome for the individual or environment known in advance?</td>
<td></td>
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<tr>
<td>Implicit Assumption: Important knowledge exists in a few special people (e.g., experts) who should tell others what to do.</td>
<td>Implicit Assumption: Important knowledge exists in individuals throughout the system and may be context-dependent.</td>
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Four Basic Change Models

- Emergent: Encourage/Support individuals to develop new teaching conceptions and/or practices and encourage use e.g., Dissemination/training (SER, FDR), focused conceptual change (FDR)
- Prescribed: Tell/Teach individuals about new teaching conceptions and/or practices. e.g., reflective practice (FDR)
- Developed new environmental features that require/encourage new conceptions and/or behaviors that will likely lead to changes in instruction e.g., policy change (HER)
- Empower/Catalyze stakeholders to develop new environments that will likely lead to changes in instruction that they value, e.g., Institutional Transformation (HER), learning organizations (HER)

Each Model has a Unique Focus for Change

- Emergent: Teachers, Culture
- Prescribed: Curriculum/Pedagogy, Policy

Each Model has a Unique Change Agent Role

- Emergent: Encourage, Empower/Catalyze
- Prescribed: Teach, Command
Each Model has a Unique Literature Base

Discipline of Authors Align As Expected

Weaknesses of Each Model Related to Others

Strengths and Weaknesses

Summary: Four Basic Change Models

Implications
A Conference to Address These Issues

One Approach: Co-Teaching*
Developing Faculty Experience with new methods – Part of PhysTEC

CH: Experienced faculty member in WMU PhysTEC courses, experienced PER researcher with knowledge about many PER instructional interventions, co-teaching participant

MF: New faculty member in WMU Physics Dept., all prior teaching experience as a TA, some familiarity with PER via grad study at OSU, co-teaching participant

AB: Faculty member in college of education, experience evaluating instructional changes in college faculty, outside observer of co-teaching

Co-Teaching: Why?
Goal: Enculturate MF into PhysTEC teaching
• Help MF understand how and why PhysTEC courses work through direct experience – and to see that it does work.
• Reduce the risks of instructional experimentation by working with an experienced instructor.
• Help MF develop a repertoire of materials and strategies that can be used in subsequent PhysTEC-style courses.

Co-Teaching*: What?
• Fall 2005: CH and MF co-taught Phys 2050: Introductory Calculus-Based Mechanics
  – CH and MF alternate being in charge of class each week
  – Weekly meetings between CH and MF to reflect on previous week and discuss initial plans for coming week
  – Course structure set up by CH to support PhysTEC design principles
  – MF had access to materials used by CH in previous semesters
• Spring 2006: MF teaches Phys 2050 on his own

Data Collected
– Individual interviews (conducted by AB) with CH and MF at beginning, middle, end of semester
– Teaching observations (conducted by AB) of CH and MF at beginning, middle, end of semester

Results: MF Instructional Practices
• Observed instructional practices were consistent with PhysTEC principles from the start
  – Few differences observed between MF and CH
• MF instruction likely would have been more traditional without co-teaching:
  – “I probably wouldn’t do as many in-class activities as we are doing now... and so it will probably be a little bit more like the formal lecture.” (F1#228-233)

* More info about co-teaching in K-12 settings is available in Roth and Tobin (2002).
Results: MF Beliefs

Initial Beliefs: Skeptical

“When I first came I was skeptical about having students do nothing but problems in class. Just sort of standing by while they do problems.” (F2#64-87)

Mid-term Beliefs: Some parts are OK

“It taught me something that I am going to adopt aspects of in future courses. You know, pick up the things that I think are working really well and the interactive and the discussions, things that are really useful.” (F2#194-198)

End of term Beliefs: It is working very well

“My class is going to be very similar to what we did last semester, even the structure will be the same structure. It’s going to be almost identical.” (F3#272-273)

Conclusions

1. It worked!
   - Significant changes documented in beliefs and intentions.
2. Course structure was important.
   - Practices started out in PhysTEC mode and did not change. This was likely due to course structure that constrained possibilities.
3. Affordable
   - Cost $2,800 to hire a part-time instructor to cover 1 class.
4. The entire semester was necessary
   - Although practices did not change, beliefs and intentions continued to change throughout the semester.
5. Co-teaching was important
   - Not student-teacher or mentor-mentee, but collegial relationship. “Well the thing that I liked the most about this is it wasn’t like I was Charles’ protégé. He recognizes me as a colleague and we were teaching this class together. . . . it wasn’t like teacher-apprenticeship which at this level it might seem sort of insulting.” (F3#283-286)

Implications

• Co-teaching is a cost-effective model that shows significant promise as a way to promote research-consistent instruction in new faculty.
• It may also be an applicable for graduate students or experienced faculty.
• Significant Limitation
  - Co-teaching only works when there is a teacher available who teaches in a research-consistent manner.

Summary: Four Basic Change Models

An appropriate change strategy should address all four 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.

Most SER strategies address only curriculum/pedagogy.