Barriers to Instructional Change

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

April 3, 2008

Dr. Charles Henderson
Western Michigan University

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

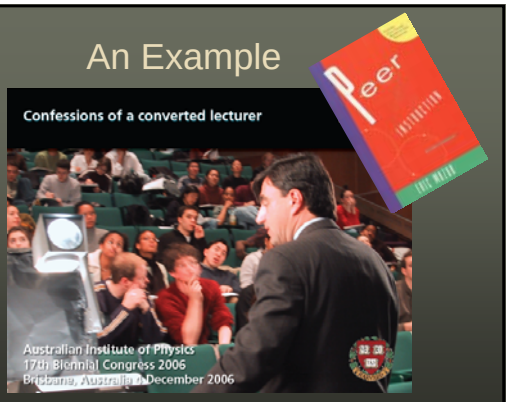
- Critique of PER Change Strategy – Curriculum Development & Dissemination
- Framework for Thinking about Change Strategies
- Co-Teaching – Example of a Potentially Productive Change Strategy

General Features of PER Dissemination

Talks – Papers – Workshops – Books

1. Aimed at changing individual instructors.
2. Transmission-oriented with five main segments:
   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…)
   5. Often implementation of strategy is supported with curricular materials, books, etc.

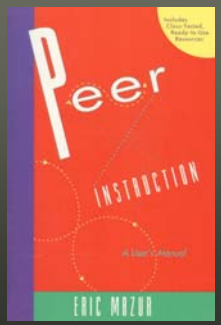
An Example



From: http://mazur-www.harvard.edu/

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[1]. "Most" teach physics.
- Just-in-Time Teaching (JiTT)
  - 71 United States physics instructors who use JiTT for introductory physics[2].
- There are ~11,360 physics faculty employed in two-year and four-year colleges in the United States[3,4].
  - Peer Instruction – 3.1% of faculty
  - JiTT – 0.6% of faculty

1. Fagen, A. P., Crouch, C. H. and Mazur, E. (2002) Peer instruction: Results from a range of classrooms. *The Physics Teacher* 40, 206-209.
2. Novak, G. M. (2004) JiTT impact and citations. Retrieved February 12, 2007, from Just-in-Time Teaching web site: http://webphysics.iupui.edu/jitt/impact.html.
3. Ivie, R., Stowe, K. and Nies, K. (2003) *2002 physics academic workforce report* (AIP Pub. Number R-392.5) American Institute of Physics.
4. McFarling, M. and Neuschatz, M. (2003) *Physics in the two-year colleges: 2001-02* (AIP Pub. Number R-436) American Institute of Physics.

Experts Consider Use of PER to Be Low

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

  J. Handelsman, D. Ebert-May, R. Beichner, P. Bruns, A. Chang, R. DeHaan, J. Gentile, S. Lauffer, J. Stewart, S. M. Tilghman and W. B. Wood, "Education: Scientific teaching," Science. 304 (5670), 521-522 (2004). 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."

  C. Henderson and T. Stelzer, "The gap between PER and mainstream faculty: The PER perspective," (Poster presented at the Foundations and Frontiers in Physics Education Research Conference, Bar Harbor, Maine, August 16, 2005, 2005). 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."

  National Research Council, Improving undergraduate instruction in science, technology, engineering, and mathematics: Report of a workshop (The National Academies Press, Washington, D.C., 2003).

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.

The Importance of Environmental Characteristics

- Instructors teach traditionally even when they
  - Recognize a need for improvement and are seeking ideas for change
  - Put considerable time and effort into their teaching
  - Have beliefs consistent with reform
  - Are familiar with research results and respect these results
  - Have access to curricular materials

Henderson, C. and Dancy, M. (2007) Barriers to the Use of Research-Based Instructional Strategies: The Influence of Both Individual and Situational Characteristics. *Physical Review Special Topics: Physics Education Research*, 3 (2), 020102.

One Reason: Restrictive Environments

Institutions are set up for traditional instruction

Physical Infrastructure

Institutional Expectations

Departmental Norms

Henderson, C. and Dancy, M. (2007) Barriers to the Use of Research-Based Instructional Strategies: The Influence of Both Individual and Situational Characteristics. *Physical Review Special Topics: Physics Education Research*, **3** (2), 020102.

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. Newton's Laws
6. Work and Energy
7. Systems of Particles
8. Conservation of Momentum
9. Rotation
10. Static Equilibrium
11. Gravity
12. Elastic Properties of Solids
13. Mechanics of Fluids
14. Ideal Gas Law
15. First Law of Thermodynamics
16. Second Law of Thermodynamics
17. Oscillations
18. Waves on a String
19. Sound

Student Expectations
(the *hidden contract*)

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

	Adoption	Adaptation	Reinvention	Invention
Develop Basic Idea	PER			
Develop Essential Features			Teacher (maybe in conjunction with PER)	
Develop Details				Teacher
Implement				

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**

*Henderson, C. and Dancy, M. (2008) Physics Faculty and Educational Researchers: Divergent Expectations as Barriers to the Diffusion of Innovations. *American Journal of Physics (Physics Education Research Section)*, 76 (1), 79-91.

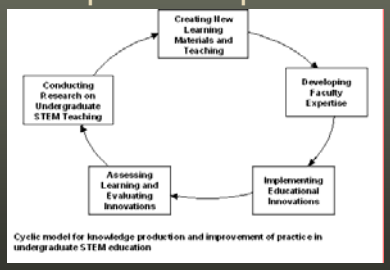
Henderson, C. (2008) Promoting Instructional Change in New Faculty: An Evaluation of the Physics and Astronomy New Faculty Workshop. *American Journal of Physics*, **76 (2), 179-187.

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)*

Henderson, C. and Dancy, M. (2008) Physics Faculty and Educational Researchers: Divergent Expectations as Barriers to the Diffusion of Innovations. *American Journal of Physics (Physics Education Research Section)*, 76 (1), 79-91.

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

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

Disciplinary Science Education Researchers (SER)

Seymour, E. (2001) Tracking the process of change in us undergraduate education in science, mathematics, engineering, and technology. *Science Education* 86, 79-105.

Faculty Development Researchers (FDR)

Emerson, J. D. and Mosteller, F. (2000) Development programs for college faculty: Preparing for the twenty-first century. In *Educational media and technology yearbook 2000* (Vol. 25) (Branch, R.M. and Fitzgerald, M.A., eds.), pp. 26-42.

Higher Education Researchers (HER)

Kezar, A. J. (2001) Understanding and facilitating organizational change in the 21st century: Recent research and conceptualizations. *ASHE-ERIC Higher Education Report* 28 (4), 1-162. (Available online: http://dx.doi.org/10.1002/aehe.2804)

Three Groups - One Common Goal

Transform undergraduate education from the instruction paradigm to the learning paradigm.

CHART 1
COMPARING EDUCATIONAL PARADIGMS

The Instruction Paradigm	The Learning Paradigm
Mission and Purposes	
Provide/deliver instruction	Produce learning
Transfer knowledge from faculty to students	Elicit student discovery and construction of knowledge
Offer courses and programs	Create powerful learning environments
Improve the quality of instruction	Improve the quality of learning
Achieve access for diverse students	Achieve success for diverse students
Teaching/Learning Structures	
Atomistic; parts prior to whole	Holistic; whole prior to parts
Time held constant, learning varies	Learning held constant, time varies
50-minute lecture, 3-unit course	Learning environments
Classes start/end at same time	Environment ready when student is
One teacher, one classroom	Whatever learning experience works
Independent disciplines, departments	Cross discipline/department collaboration
Covering material	Specified learning results
End-of-course assessment	Pre/during/post assessments
Grading within classes by instructors	External evaluations of learning
Private assessment	Public assessment
Degree equals accumulated credit hours	Degree equals demonstrated knowledge and skills

From Barr, R. B. and Tagg, J. (1995) From teaching to learning - a new paradigm for undergraduate education. *Change* (November/December), 13-25.

Three Groups – No Communication

No overlap in references! → No communication between groups

Field	Article	Number of References
[SER]	Seymour (2001)	77
[FDR]	Emerson & Mosteller (2000)	34
[HER]	Kezar (2001)	280

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)

*Supported by NSF DRL-0723699

Categorized along two Important Dimensions

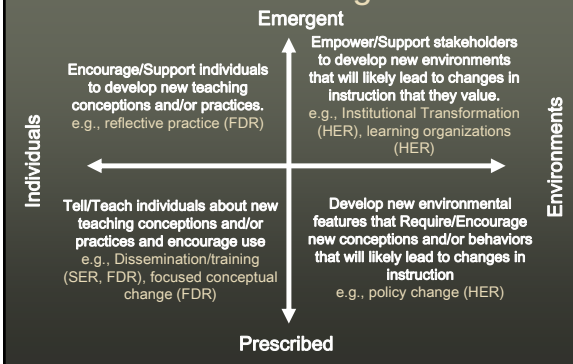
What is the primary aspect of the system that the change approach seeks to directly impact?

Individuals	Environments
Implicit Assumption: Individuals' actions primarily influenced by their own volition	Implicit Assumption: Individuals' actions are primarily influenced by external environments

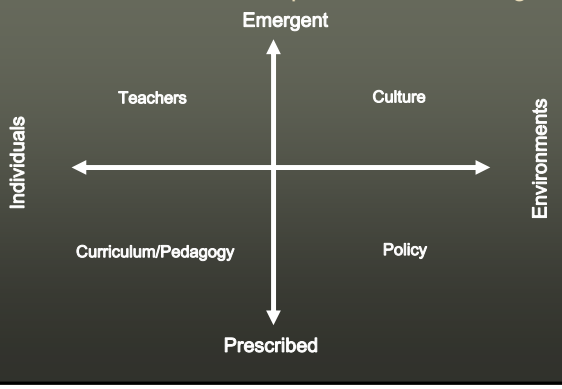
To what extent is the intended outcome for the individual or environment known in advance?

Prescribed	Emergent
Implicit Assumption: Important knowledge exists in a few special people (e.g., experts) who should tell others what to do.	Implicit Assumption: Important knowledge exists in individuals throughout the system and may be context-dependent.

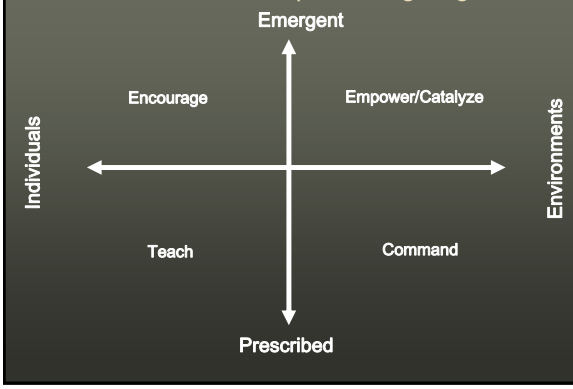
Four Basic Change Models



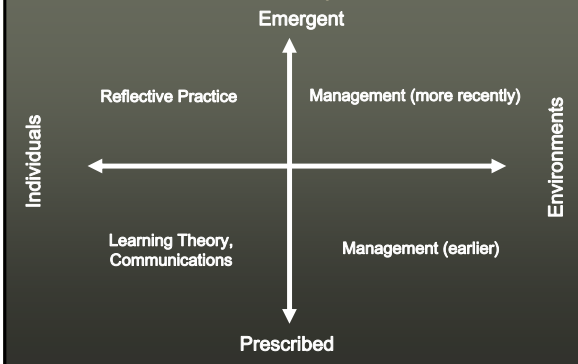
Each Model has a Unique Focus for Change



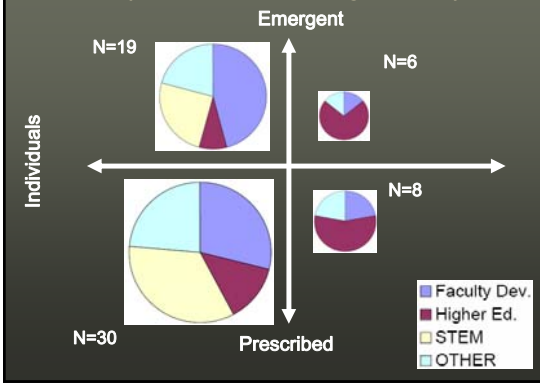
Each Model has a Unique Change Agent Role



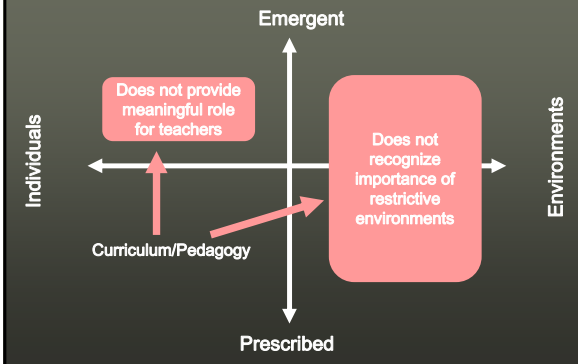
Each Model has a Unique Literature Base



Discipline of Authors Align As Expected



Weaknesses of Each Model Related to Others



Strengths and Weaknesses

	Curriculum/ Pedagogy	Teachers	Policy	Culture
Strengths	-Developing good curricula is beyond the skills and available time of most faculty	-Treats faculty as professionals -Customization of curricula is typically necessary	-Recognizes that traditional structures are barriers to lasting change	-Recognizes that group norms (i.e., cultures) are not easily changed by policy changes
Weaknesses	-Faculty may use curricula inappropriately (or not at all) -Most effective curricula conflict with traditional environments	-Faculty working alone may reinvent the wheel -Traditional environments do not reward a focus on teaching	-Faculty may subvert policy changes -Loose coupling of university environments complicate top-down efforts	-No clear guidance for change agents

Summary: Four Basic Change Models

Teachers	Culture
Curriculum/ Pedagogy	Policy

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.

Implications

Stronger change models may be developed by combining strengths of existing models.

A Conference to Address These Issues

A Promising Approach: Co-Teaching

Teachers	Culture
Curriculum/ Pedagogy	Policy

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.

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

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)

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#84-87)

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

Teachers	Culture
Curriculum/ Pedagogy	Policy

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.