"Build it and they will come", and other myths about science education reform

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Abstract

Reform-minded science educators have focused much energy developing high quality curricular materials with the expectation that science instructors will recognize the superiority of these materials and adopt them. Adoption is assumed to be an unproblematic process and the expectation is that the number of faculty using these materials will naturally expand, eventually leading to a critical mass of instructors teaching in a fundamentally new way. Unfortunately, current and historical evidence does not indicate promise for this approach to reform. This talk will focus on the importance of understanding college science instructors and the contexts within which they work when planning instructional reforms. Specific examples will be given from several empirical studies of college physics faculty.

What physics education research has done…

Identified many problems with traditional methods of instruction.

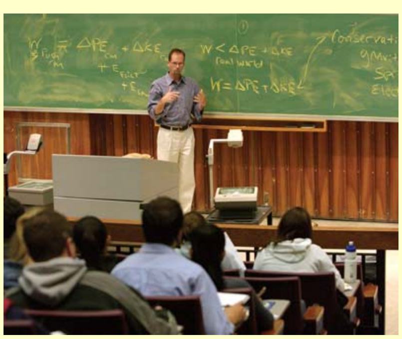
- **Ineffective at developing understanding of physics concepts, problem-solving skills, and understanding of the processes of science**
- **Students often develop negative attitudes towards science.**
- **High attrition rates, especially for women and racial minorities.**

Found Solutions!

Replace lecture with hands-on, inquiry based activities.

Encourage and support cooperative learning.

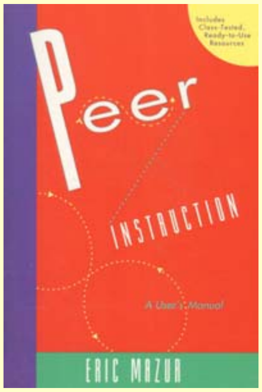
Explicitly teach problem solving.

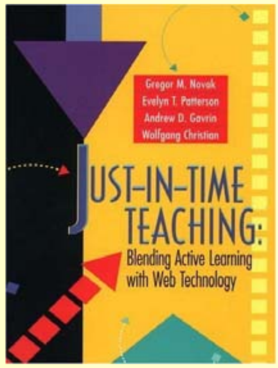


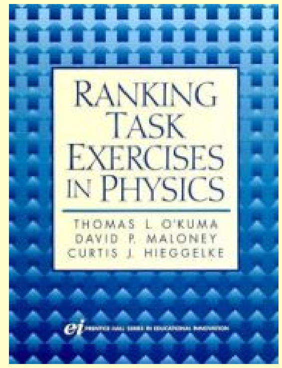
Traditional Physics class at University of Rochester

SCALE-UP Physics class at Clemson University

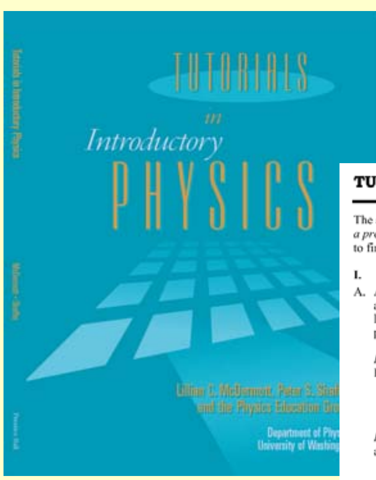
Classroom-Tested, Ready-to-Use Materials and Strategies

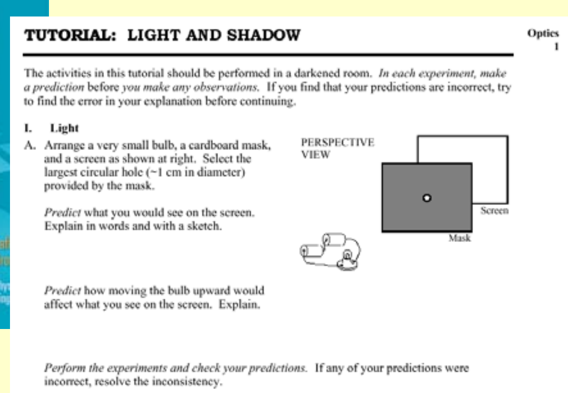






Research-Based Tutorials





TUTORIAL: LIGHT AND SHADOW Optics 1

The activities in this tutorial should be performed in a darkened room. *In each experiment, make a prediction before you make any observations.* If you find that your predictions are incorrect, try to find the error in your explanation before continuing.

I. **Light**

A. Arrange a very small bulb, a cardboard mask, and a screen as shown at right. Select the largest circular hole (~1 cm in diameter) provided by the mask.

Predict what you would see on the screen. Explain in words and with a sketch.

PERSPECTIVE VIEW

Screen

Mask

Predict how moving the bulb upward would affect what you see on the screen. Explain.

Perform the experiments and check your predictions. If any of your predictions were incorrect, resolve the inconsistency.

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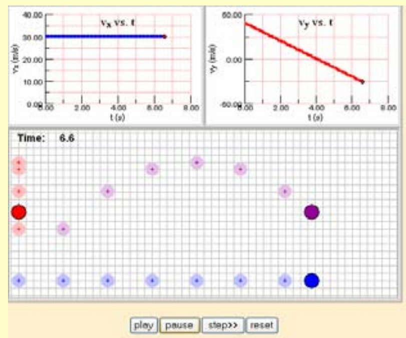
Technology

Classroom Response Systems

Java Applets



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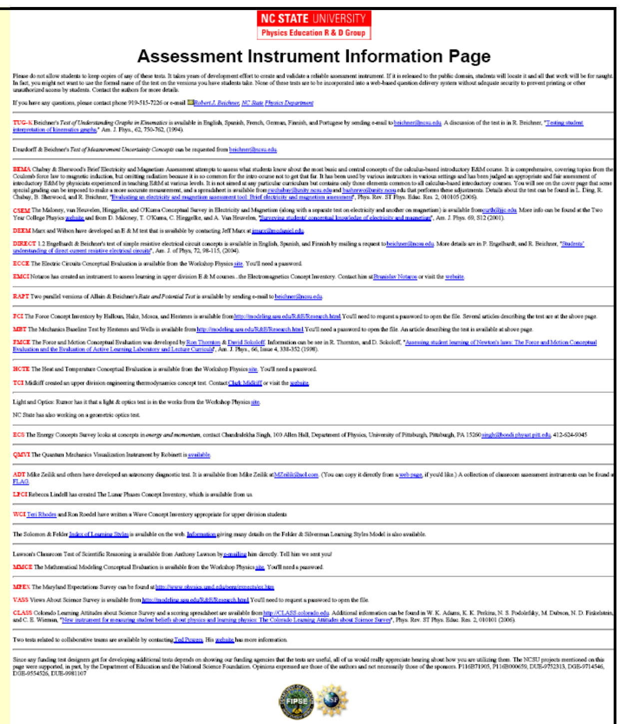
Research-Based Nationally-Normed Assessments

From: http://www.ncsu.edu/per/TestInfo.html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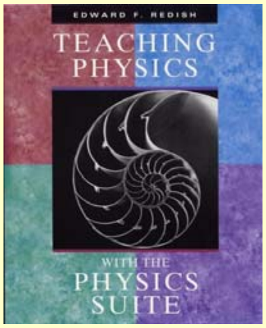
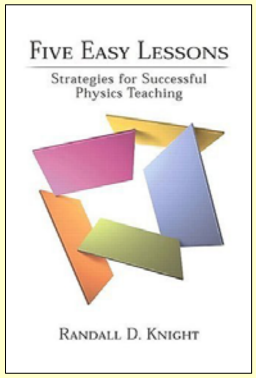
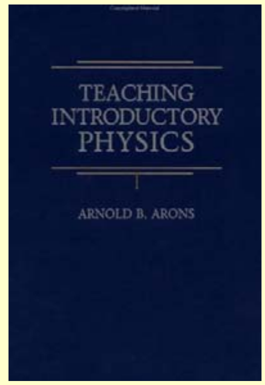
Physics Education R & D Group

Assessment Instrument Information Page

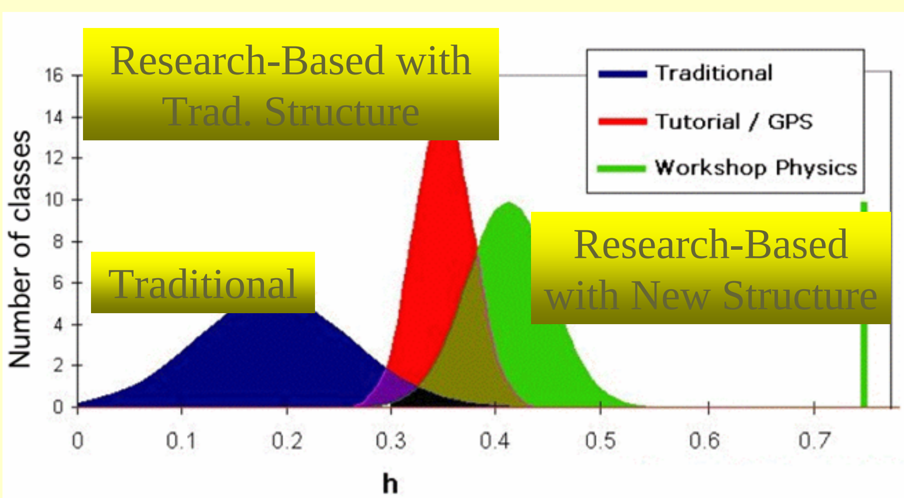
Books that summarize it all!







Evidence that Research-Based Reform Works!



Student learning gains on the Force Concept Inventory

From J. M. Saul and E. F. Redish, "Final Evaluation Report for FIPSE Grant #P116P50026: Evaluation of the Workshop Physics Dissemination Project," (University of Maryland, 1997).

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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 physics classrooms.

Why is research-based reform so slow and difficult?

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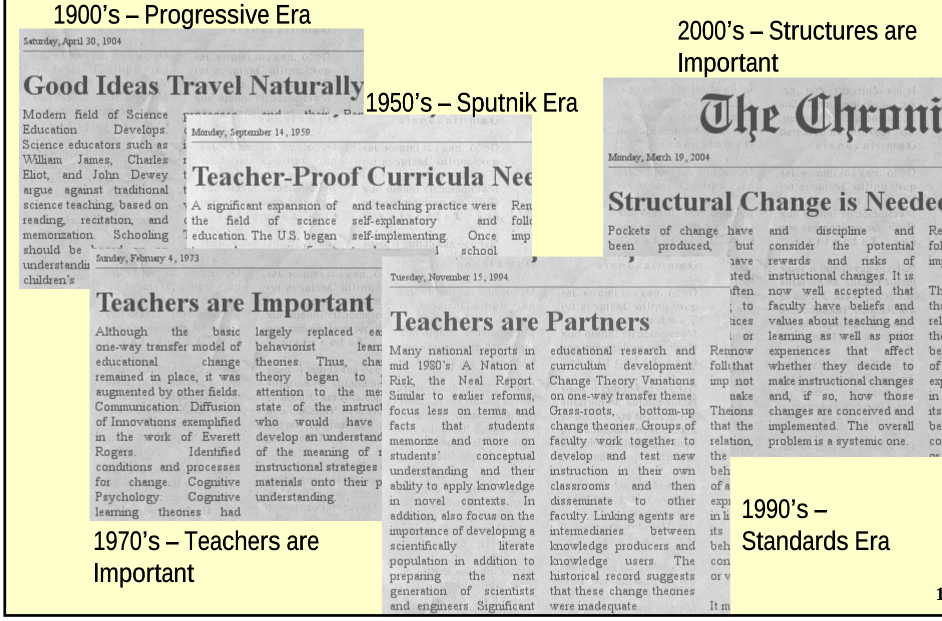
A Very Brief History of Change in Discourse on Reform of Science Education

1900's – Progressive Era

1950's – Sputnik Era

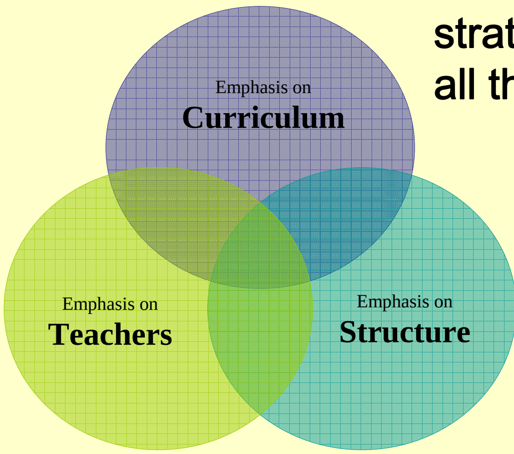
2000's – Structures are Important



1970's – Teachers are Important

1990's – Standards Era

Three Aspects of Educational Change



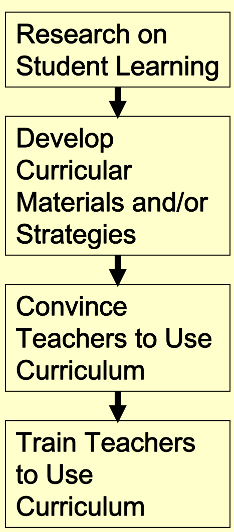
An appropriate change strategy should address all three aspects.

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.

Emphasis on Curriculum
The Dissemination Model



This is the currently the most widely used model by educational researchers – often implicit – and has been since at least the 1950's.

Examples:

- **Curricular materials and strategies disseminated by workshops, talks, papers, teacher guides, etc.**

What Does the Dissemination Model Look Like?

Attendees at Fall 2002 meeting of the NY State Section of the American Association of Physics Teachers at Binghamton University.

Traditional Physics class at University of Rochester

Emphasis on Curriculum The Dissemination Model

Problems

Often Ignores Teacher Characteristics

- Assumes that fidelity of Implementation is desirable and possible.
- Makes incorrect assumptions about teachers.

Often Ignores Structural Characteristics

- Situational characteristics typically strongly favor traditional instruction
- It is assumed that if the developer can overcome situational factors, so can other instructors.

Myth #1: Curriculum is the most important aspect of educational change.

Reality: Curriculum is necessary, but not sufficient.

Emphasis on Teachers
The Action Research Model

Continuous Cycles of*:

- Problem Formulation
- Data Collection
- Data Analysis
- Reporting of Results
- Action Planning

Main focus is on teacher ideas and teacher-directed inquiry, although some structural change is typically required since such inquiry is an unusual activity in most contexts.

Examples:

- **Scholarship of Teaching and Learning**
- **Faculty Learning Communities**
- **Lesson Study**

Problems:

- **Often ignores strongly traditional structures (e.g., time spent on action research may not be recognized in tenure decisions)**
- **Often ignores curriculum -- without appropriate introduction to existing work, teachers may reinvent rather than build on good products.**

*From R. Sagor (1992) "How to Conduct Collaborative Action Research".

Emphasis on Structure
The Structural Change Model

This model is not well known to educational researchers. It is often used by politicians at K-12 level. In higher education changes can be made at the accrediting level, the institutional level, or the departmental level.

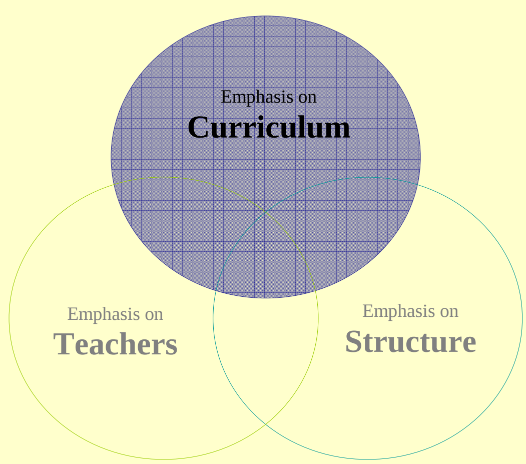
Examples:

- **Engineering Education (ABET)**
- **Increasing institutional value on "good teaching" or recognition for scholarly work in teaching and learning**
- **Departmental changes in infrastructure to support "good" teaching – e.g., SCALE-UP room, clicker technology.**

Problems:

- **Often ignores teachers -- Teachers may subvert structural changes**
- **Often ignores curriculum -- Without appropriate introduction to existing work, faculty may reinvent rather than build on good products.**

Three Aspects of Educational Change



An appropriate change strategy should address all three aspects.

Most strategies address only one – curriculum.

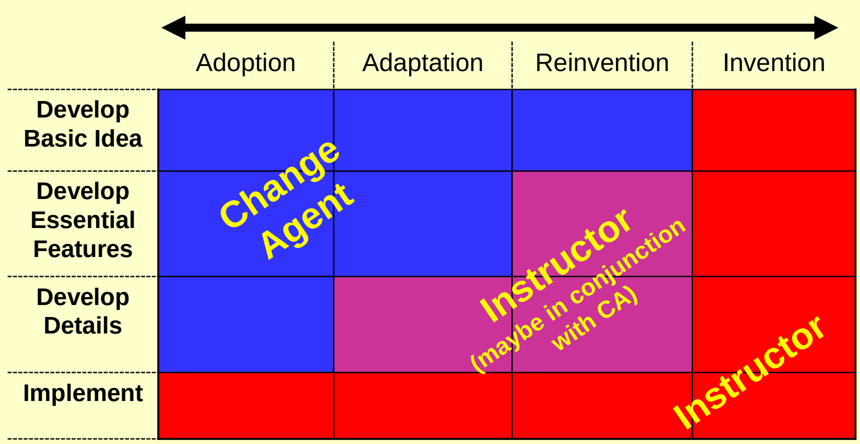
Myth #2: Curriculum should be designed to be used with fidelity

Problems:

- **Requires transfer of significant implicit knowledge**
  - fidelity only possible in an apprenticeship-based dissemination model
- **This is not what faculty want nor is it how they operate**
  - faculty want and do customize curricula.
- **Customization is typically necessary due to contextual differences**
- **Expecting fidelity is insulting to faculty because it devalues their knowledge and experience**

Adoption-Invention Continuum:

Possible Relationships Between Change Agents and Faculty



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Myth #3: Teachers teach traditionally because they have transmissionist learning theories

Problems:

- **Not true**

  faculty interviewed have rejected transmissionist learning theories and indicate that they teach in a transmissionist way due to situational constraints

- **Insulting**

  typical professional development starts by attacking transmissionist instruction and learning theories

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Myth #4: Situational factors can be overcome – My own teaching is proof by example.

Problems:

- **Situational factors (e.g., large classes, content coverage expectations) do not usually prevent many recommended teaching styles**

  they just make them more difficult for faculty to enact them

- **Situational factors do actually prevent some changes**

  for example, a course with no grades

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Empirical Support

Three Examples from Three Studies:

Example #1: Instructors may reinvent innovations based on minimal understanding.

Example #2: Faculty do not have transmissionist learning theories.

Example #3: Instructor attributes are often not the dominant factor preventing use of research-based instruction -- situational factors are.

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Example 1: Instructors may reinvent innovations based on minimal understanding.

What: Semester-long case study of one physics instructor as he attempted to change his instruction

Publications:

•Henderson, C. (2005). The challenges of instructional change under the best of circumstances: A case study of one college physics instructor. *American Journal of Physics (Physics Education Research Section)*, 73 (8), 778-786.

Assumptions of Typical Dissemination Strategies

1. Faculty first learn a lot about the innovation.
   - How it works
   - Why it works
2. Faculty then make a rational, informed decision
3. Faculty use the innovation “as is” first and then (maybe) modify for future use.

The Case - Dr. Holt

- Tenured, experienced, research university faculty
- Planning to change his instruction to improve student learning

Dr. Holt had Characteristics Necessary for Successful Change

- Dissatisfied with outcomes of previous instruction
- Learned about research-based alternatives
- Departmental Support

Data Sources

- **Weekly interviews** (15 interviews, 20-60 minutes each)
- **Daily class observations** (62 of 67 class days observed)
- **Materials distributed to students** (syllabus, exams, HW)

Example from Dr. Holt: Use of White Board Group Work

- Dr. Holt was dissatisfied with the level of student engagement in his course.
- He had heard about using white boards to promote small group discussion during class.
- He decided to implement use of white boards based only on this awareness knowledge. He developed implementation details on his own.
- Lack of knowledge led to problems:
  - Groups were assigned, but assignments not enforced.
  - Student groups were not asked to share their solutions with other groups or with the class.
  - Student group work was not graded in any way.
- Many students were not engaged in group work.

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Important Differences Between Dr. Holt's Change Process and Typical Developer Assumptions

- **Implementation decisions were made based on minimal knowledge.**
  - **Awareness knowledge, not knowledge of principles or details**
- **All innovations from external sources were changed significantly.**
  - **Ex: White board group work, problem solving procedure**
- **Innovations did not all come from external sources.**
  - **Ex: Reading Questions**

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Example #2: Faculty do not have transmissionist learning theories.

What: Artifact-based structured interviews with 6 randomly-selected research university faculty.

Publications:

•Henderson, C., Yerushalmi, E., Kuo, V., Heller, P., & Heller, K. (2004). Grading Student Problem Solutions: The Challenge of Sending a Consistent Message, *American Journal of Physics*, 72, 164-169.
•Yerushalmi, E., Henderson, C., Heller, K., & Heller, P., Kuo, V. (accepted). Physics Faculty Beliefs and Values about the Teaching and Learning of Problem Solving Part I: Mapping the Common Core, *Physical Review Special Topics: Physics Education Research*.
•Henderson, C., Yerushalmi, E., Heller, K., & Heller, P., Kuo, V. (accepted). Physics Faculty Beliefs and Values about the Teaching and Learning of Problem Solving Part II: Procedures for Measurement and Analysis, *Physical Review Special Topics: Physics Education Research*.

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Interview Structure

1½ hour open-ended interview guided by instructional artifacts:

- **3 Instructor solutions**
- **5 Student solutions**
- **4 Problem types**

All artifacts were based on one problem -- instructors were given the problem and asked to solve it on their own before the interview.

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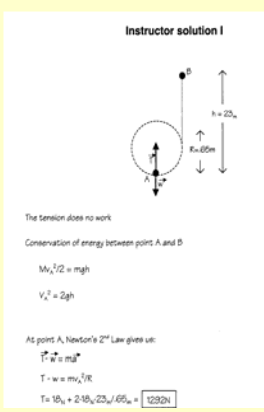
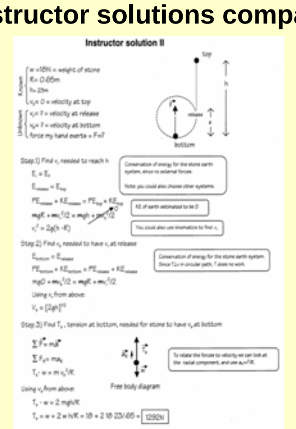
Example: Instructor Solution Artifacts and Interview Questions

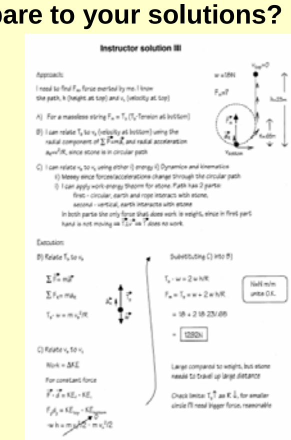
Q1: In what situations are your students provided with examples of solved problems? Why?

Q2: How would you like your students to use the solved examples you give them?

Q3: How do these instructor solutions compare to your solutions?







Analysis Procedure

Video- & audiotapes of interviews
(6 interviews x 1.5 hrs = ~9 hrs)

→ **Interview transcripts**
(~180 pages)

↓ **Statements**
(~2400)

↓ **Individual Concept Maps**
(10 x 6 = 60)

↓ **Combined Concept Maps**
(10)

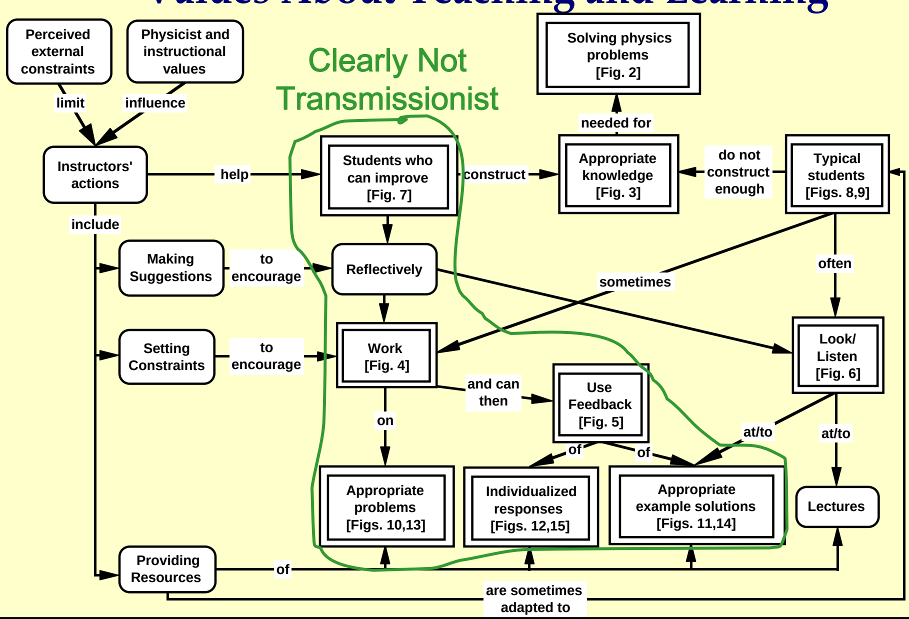
↓ **Combined Main Map**
(1)

Concept Maps allow for:

the reduction of complex data into visual representations

explicit connections to be made between ideas that can then be tested

Model of Physics Instructor Beliefs and Values About Teaching and Learning



Example #3: Instructor attributes are often not the dominant factor preventing use of research-based instruction -- situational factors are.

What: Interviews with 5 likely users of educational research

Publications:

Henderson, C. and Dancy, M. (submitted) Physics Faculty and Educational Researchers: Divergent Expectations as Barriers to the Diffusion of Innovations. Submitted April 2006 to *American Journal of Physics (Physics Education Research Section).*

"Best Case" Faculty Project

Interviews with five physics faculty

- **4 institutions** (Research, Regional, Liberal Arts)
- **Senior and tenured**
- **Dedicated and highly regarded teachers**

In theory, this group should be likely to incorporate research-based methods

Asked about

- **Current practice**
- **Instructional Goals**
- **Beliefs**
- **Experiences with change**
- **Experiences with education research(ers)**

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Findings

In general instructors…

- Saw a need for change
- Knew about alternatives
- Had tried or seriously considered many of the alternatives
- Taught mostly traditionally

Blamed restrictive situational factors for lack of change

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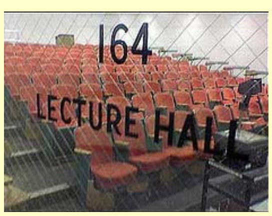
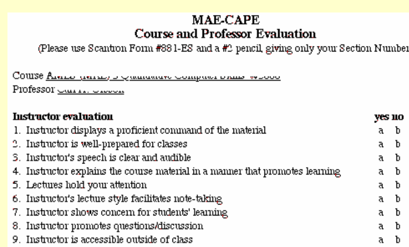
Self-Identified Restrictive Situational Factors

Institutions are set up for traditional instruction.



Physical Infrastructure



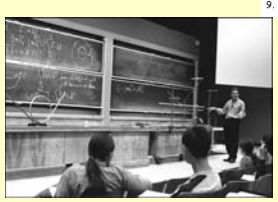
MAE-CAPE
Course and Professor Evaluation
(Please use Scantron Form #881-ES and a #2 pencil, giving only your Section Number)

Course
Professor

Instructor evaluation	yes	no
1. Instructor displays a proficient command of the material	a	b
2. Instructor is well-prepared for classes	a	b
3. Instructor's speech is clear and audible	a	b
4. Instructor explains the course material in a manner that promotes learning	a	b
5. Lectures hold your attention	a	b
6. Instructor's lecture style facilitates note-taking	a	b
7. Instructor shows concern for students' learning	a	b
8. Instructor promotes questions/discussion	a	b
9. Instructor is accessible outside of class	a	b

Institutional Expectations

Departmental Norms



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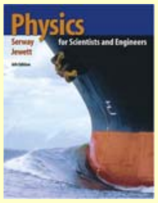
Self-Identified Restrictive Situational Factors



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


For the New Teacher

When Is a Good Day Teaching a Bad Thing?

Timothy F. Slater

Student Expectations
(the *hidden contract*)

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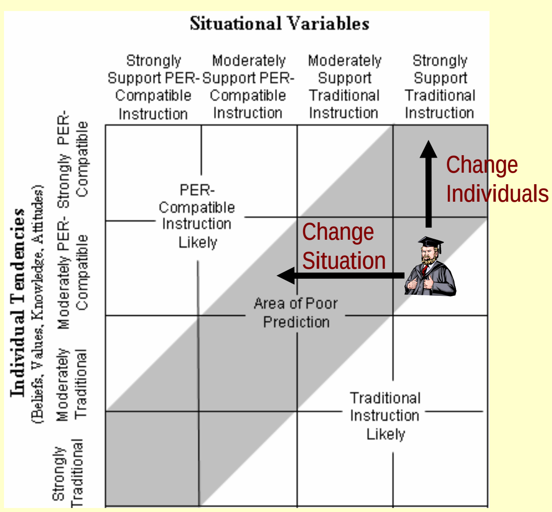
Role of Situational Factors



Promoting change in individual faculty is not enough to promote widespread change given the current strongly traditional situational variables

Model for predicting behavior based on beliefs and context adapted from L. G. Warner and M. L. DeFleur, "Attitude as an interactional concept: Social constraint and social distance as intervening variables between attitude and action," *American Sociological Review* 34 (2), 153-169 (1969).

Summary

Educational researchers have made significant progress in:

- Understanding Student Learning
- Designing effective curriculum based on this understanding

This emphasis on curriculum has:

1. not produced widespread change
2. led to several myths that minimize focus on the important areas of teacher and situation

Summary - Myths

Myth #1: Curriculum is the most important aspect of educational change.

Reality: Curriculum is necessary, but not sufficient.

Myth #2: Curriculum should be designed to be used with fidelity

Reality: Fidelity is not practical and does not match with faculty expectations.

Myth #3: Teachers teach traditionally because they have transmissionist learning theories

Reality: Traditional teaching results from a complicated interaction between teacher and situational characteristics.

Myth #4: Situational factors can be overcome – my own teaching is proof by example.

Reality: With strong enough teacher characteristics many situational barriers can be overcome, yet such changes require significant teacher effort and are not likely to be maintained.

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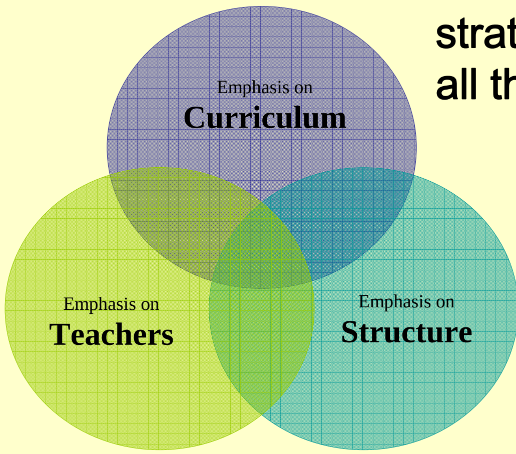
Implications



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.

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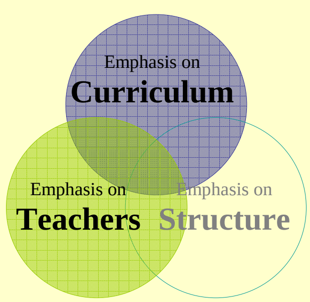
A Promising Approach: Promote Teacher Customization



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

Examples:

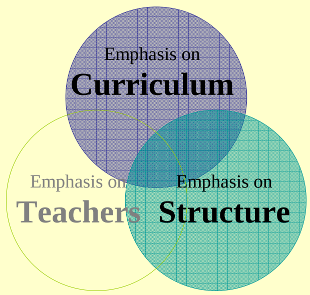
•Weizmann Institute (Israel) – Ongoing teacher workshops focused on promoting student self-monitoring in problem solving

E. Yerushalmi and B. Eylon, "Teachers' Approaches To Promoting Self-Monitoring In Physics Problem Solving By Their Students," Proceedings of the International GIREP Conference on Physics Teacher Education beyond 2000. (2001).

•University of Maryland – Open-source tutorials integrated with professional development materials

http://www2.physics.umd.edu/~elby/CCLI/index.html

Another Promising Approach: Department-Level Structural Change



Change departmental structures and curriculum. Ensure that changes do not conflict deeply with faculty 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

D. K. Campbell, C. M. Elliot and G. E. Gladding, "Parallel Parking an Aircraft Carrier: Revising the Calculus-Based Introductory Physics Sequence at Illinois," Forum on Education Newsletter of the American Physical Society. (Summer), 9-11 (1997). [http://www.aps.org/units/fed/newsletters/aug97/index.cfm#campbell]

The End

Questions/Comments

I will post a copy of this talk on my web page:
http://homepages.wmich.edu/~chenders/