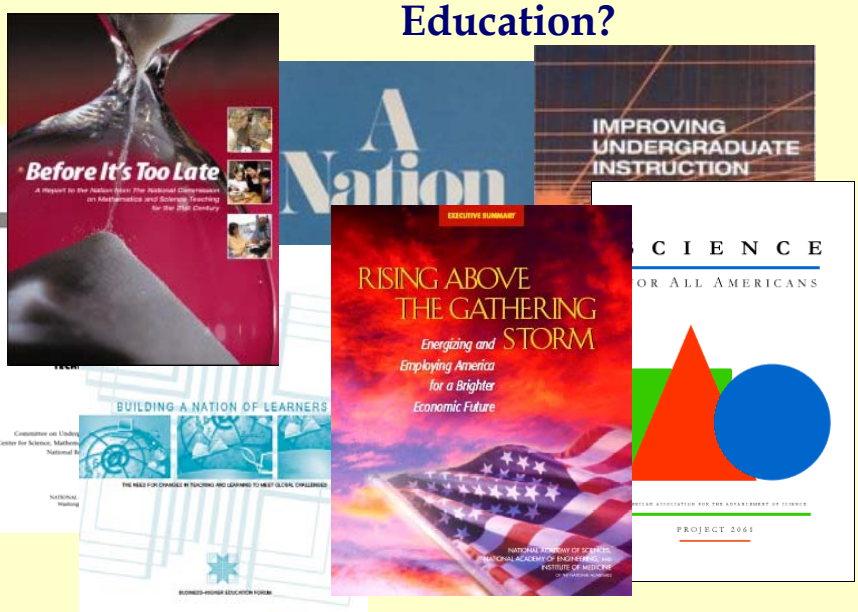
Preliminary Categorization of Change Strategies

Charles Henderson
Andrea Beach
Noah Finkelstein
R. Sam Larson

What's the Problem with STEM Education?



Facilitating Change in STEM Undergraduate Education

Economic growth and national competitiveness depend on improved STEM education

- The nature of jobs is changing.
- We do not produce enough STEM graduates.
- Many STEM graduates are not well-prepared.
- College does not help many non-STEM graduates develop an understanding of science or quantitative and logical reasoning abilities.

PKAL Report on Reports – Overview of 20+ reports published from 2003-2005

Facilitating Change in STEM Undergraduate Education

Percentage of 24-year-olds with a university STEM degree

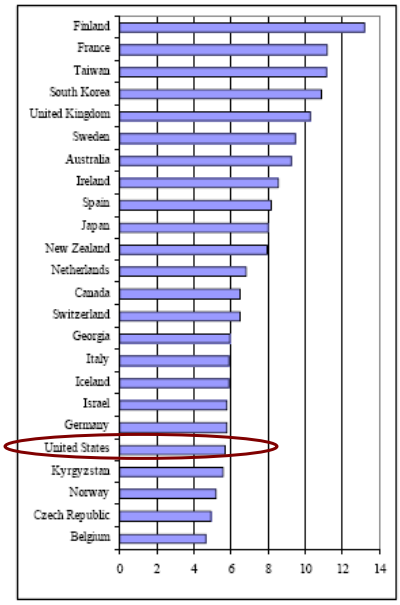


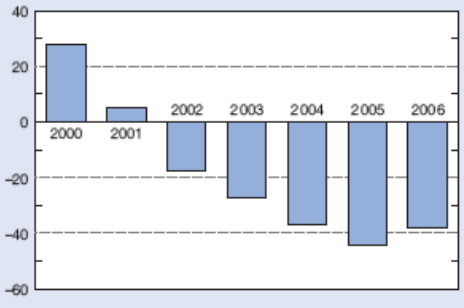
FIGURE 3-19 Percentage of 24-year-olds with first university degrees in natural sciences or engineering, 2000 or most recent year.

SOURCE: National Science Board. 2004. *Science and Engineering Indicators 2004* (NSB 04-1). Arlington, VA: National Science Foundation, Appendix Table 2-35

From "Rising Above the Gathering Storm"

More Technology Imports than Exports

Figure O-13
U.S. trade balance in high-technology goods: 2000–06

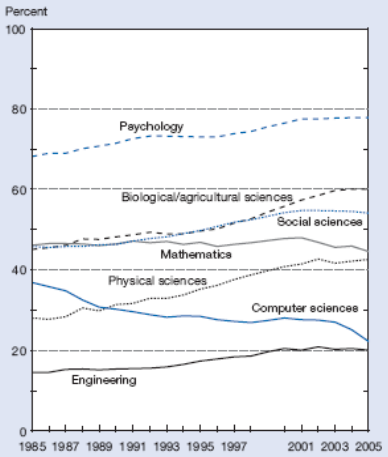


SOURCE: Census Bureau, Foreign Trade Division, special tabulations.

Science and Engineering Indicators 2008

Females
(and minorities)
Underrepresented in Many STEM Fields

Figure 2-15
Female share of S&E bachelor's degrees, by field: 1985–2005



NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-27.

Science and Engineering Indicators 2008

Poor Scientific Literacy

Table 7-5
Correct answers to scientific literacy questions, by sex: 2001, 2004, and 2006
(Percent)

Question	2001	2004	2006
Physical science			
The center of the Earth is very hot. (True)			
Male	85	86	85
Female	76	72	75
All radioactivity is man-made. (False)			
Male	81	82	77
Female	71	66	64
Lasers work by focusing sound waves. (False)			
Male	61	59	62
Female	30	28	32
Electrons are smaller than atoms. (True)			
Male	52	52	61
Female	43	39	48
The universe began with a huge explosion. (True)			
Male	43	41	40
Female	24	27	27
The continents have been moving their location for millions of years and will continue to move. (True)			
Male	83	85	85
Female	74	71	75
Does the Earth go around the Sun, or does the Sun go around the Earth? (Earth around Sun)			
How long does it take for the Earth to go around the Sun? (One year)			
Male	66	NA[a]	66
Female	42	NA	46

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); University of Michigan, Survey of Consumer Attitudes (2004); and University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix tables 7-5 and 7-6.

Science and Engineering Indicators 2008

An Important Part of the Solution → Change the Way STEM is Taught

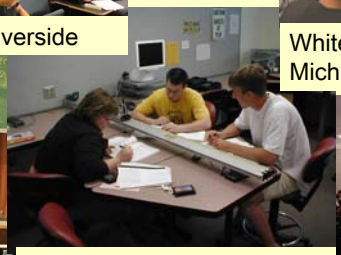
- **There is a need for inquiry-based learning that brings students "to a deep understanding of the nature of science, the language of mathematics, and the tools of technology."** (Project Kaleidoscope, ***Report on Reports II***, 2006)
- **"Educators must provide more engaging, relevant content targeted to individual styles of learning and needs."** (Business Higher Education Forum, ***Building a Nation of Learners: The Need for Changes in Teaching and Learning to Meet Global Challenges***, 2003)
- **"Departments and faculty need to utilize this educational research to guide curricular and pedagogical reform."** (National Research Council, ***BIO 2010: Transforming Undergraduate Education for Future Research Biologists***, 2003)

Some Examples of "Reformed" Instruction

Clicker use at UC Riverside

White boards at Western Michigan University

Traditional Physics class at University of Rochester



Workshop Physics Classroom at Dickinson College

SCALE-UP Physics class at Clemson University

Proposed Starting Point: Current State of Knowledge

- **We know a lot about:**
  - **effective teaching and learning of STEM subjects**
  - **how to apply this knowledge in individual classrooms**
- **A significant problem is finding ways to scale these effective practices so that all undergraduate students experience them.**

Three Groups Focused on Change in Undergraduate STEM Instruction

Disciplinary STEM Education Researchers (SER)

Housed in the STEM disciplines in College of Arts and Sciences or Engineering, Sometimes in College of Education

Faculty Development Researchers (FDR)

Housed in Center for Teaching and Learning

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)

Facilitating Change in STEM Undergraduate Education

Three Groups - One Common Goal

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

The Instruction Paradigm	The Learning Paradigm
•Deliver instruction	•Produce learning
•Achieve access for diverse students	•Achieve success for diverse students
•Independent disciplines, departments	•Cross discipline/department collaboration
•Covering material	•Specified learning results
•Grading within classes by instructors	•External evaluations of learning
•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.

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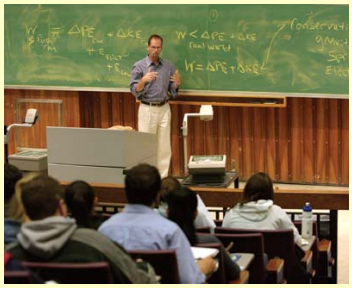
 Traditional Physics class at University of Rochester	 Clicker use at UC Riverside  White boards at Western Michigan University  Workshop Physics Classroom at Dickinson College  SCALE-UP Physics class at Clemson University

*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: Research Questions

1. What strategies do change agents use to promote improvement of undergraduate STEM instructional practices?
2. How do change strategies described by articles relate to the disciplinary background of the authors (i.e., SER, FDR, HER)?
3. What evidence is available to support the effectiveness of these strategies?
4. What common ideas about instructional change are evident in the literature?
5. How is the broader change literature (e.g., individual and organizational change theories) used by authors to frame their use or study of change strategies?

*Supported by NSF DRL-0723699

A Larger Literature Review: Overview*

Time Line:

- **Fall 2007: Literature Search**
  - literature related to promoting change in instructional practices used in undergraduate STEM
  - 295 relevant journal articles identified
- **Winter 2007-2008: Identify important article features**
  - develop article coding criteria
- **Spring 2008: Analysis of 130 articles (randomly selected from the 295)**
  - Identify four categories of change strategies
- **Spring 2008: further analysis of 43 articles**
  - Identify subcategories

*Supported by NSF DRL-0723699

Literature Search

- **Primary Databases: Web of Science, ERIC**
- **Search Terms: change, improvement, reform, teaching, instruction, higher education, college, university, tertiary**
- **Dates: 1995-present**
- **Use Title and Abstract to determine inclusion**
- **Primarily done by WMU grad students Brian Cole and Jin Hai Zhang with supervision by Andrea Beach and Charles Henderson**

295 Articles

108 Different Journals

Most Common:

- **Innovative Higher Education (26 articles)**
- **Higher Education (21 articles)**
- **Journal of Research in Science Teaching (13 articles)**
- **Studies in Higher Education (12 articles)**
- **Change (10 articles)**
- **College Teaching (8 articles)**
- **Teaching in Higher Education (7 articles)**
- **Journal of Faculty Development (6 articles)**

Change Intervention Details			
Source of Change Intervention Details	Specific intervention studied Aspects of change intervention(s) inferred		
Unit of Change Intervention (individual to environment)	Individual or groups of individuals Department (or subgroup of department) Institution Extra-Institutional		
Change Agency (refers to the unit of change above)	Internal	External – Voluntary	External -- Involuntary
Objective of Change Intervention (refers to unit of change above)	Observable actions Ways of thinking		
Directedness of Objective (refers to unit of change above)	prescribed (directed) emergent		
Duration of Intervention	One-time Short: one day or less One-time Long: between one and six days Ongoing: longer than six days		

Develop categorization scheme of change strategies

Categorized along two Important Dimensions

1. What does the change effort intend to directly impact?

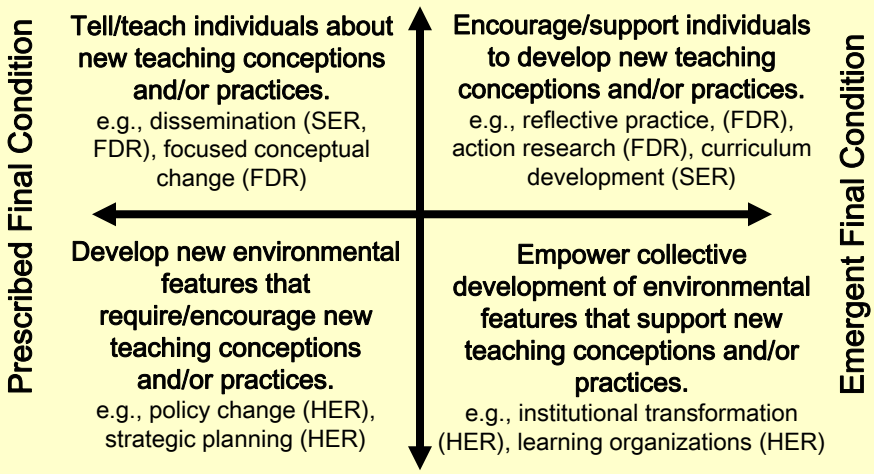
Individuals	Environments and Structures
The change intends to directly impact personal characteristics of single individuals, such as beliefs, knowledge, behaviors, etc.	The change intends to directly impact extra-individual characteristics of the system such as rules, physical characteristics of the environment, norms, etc.
Implicit Assumption: Individuals' actions are primarily influenced by their own volition	Implicit Assumption: Individuals' actions are primarily influenced by external environments

Categorized along two Important Dimensions

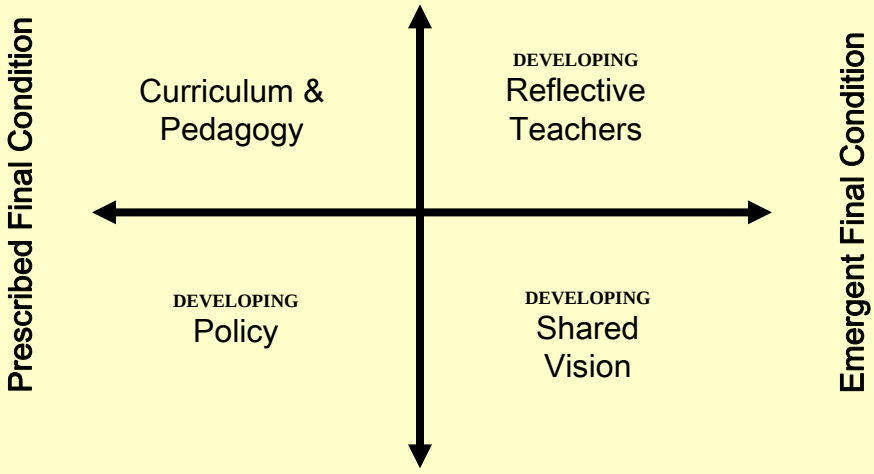
2. To what extent is the outcome prescribed in advance?

Prescribed Final State	Emergent Final State
The desired final state for the individual or environment is known at the beginning of the change process.	The desired final state for the individual or environment is developed as part of the change process.
Implicit Assumption: Important knowledge relevant to change outcome is known to a few people (e.g., experts). Therefore a small group should determine the intended outcome.	Implicit Assumption: Important knowledge relevant to change outcome exists in individuals throughout the system. Therefore a variety of stakeholders should be involved in determining the intended outcome.

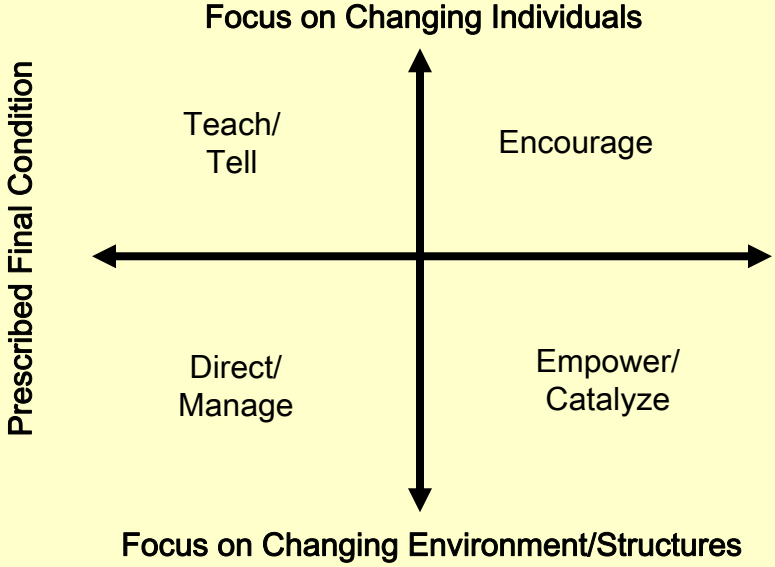
Four Categories of Change Strategies



Each Strategy has a Unique Emphasis



Each Strategy has a Unique Change Agent Role



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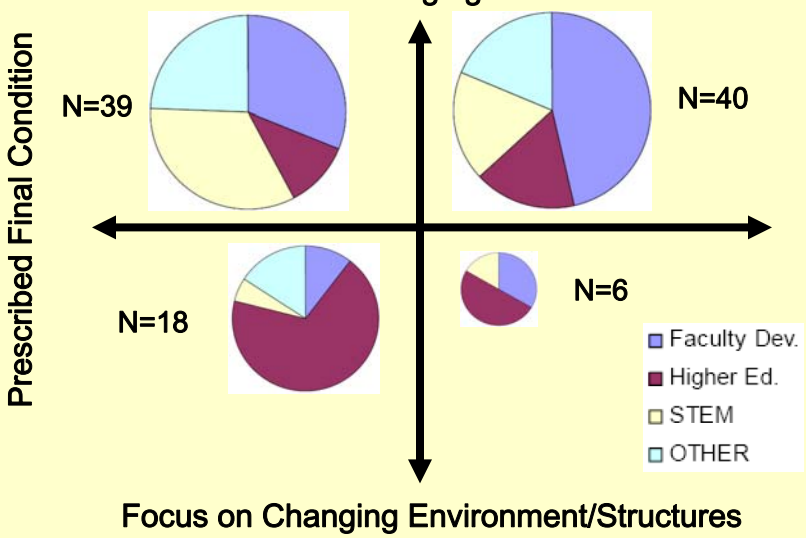
Discipline of Authors Align as Expected



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Only Four Articles Could not Be Categorized

Category	Number of Articles	Percentage
Curriculum & Pedagogy	39	30.0%
Teachers	40	30.8
Policy	18	13.8
Shared Vision	6	4.6
Not Categorizable	4	3.1
Background	9	6.9
Eliminate	14	10.8
Total	130	100

All Review Articles

•Eckel, P., Green, M., & Hill, B. (2001). Riding the waves of change: Insights from transforming institutions. *On Change V.* Washington, DC: American Council on Education.

•Emerson, J. D., & Mosteller, F. (2000). Development programs for college faculty: Preparing for the twenty-first century. In R. M. Branch & M. A. Fitzgerald (Eds.), *Educational Media and Technology Yearbook, 25*, 26-42.

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

•Weimer, M., & Lenze, L. F. (1991). Instructional interventions: A review of the literature on efforts to improve instruction. In J. C. Smart (Ed.), *Higher Education: Handbook of Theory and Research* (Vol. VII, pp. 294-333). New York: Agathon Press.

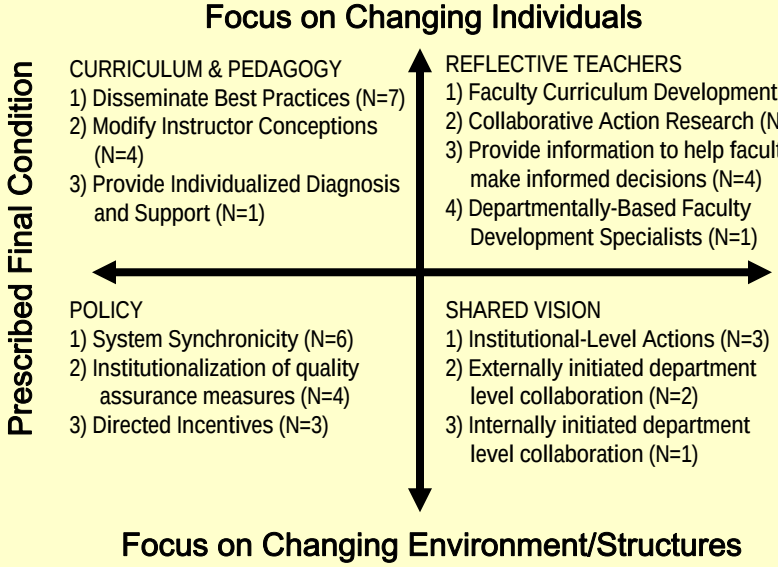
Subcategories

More detailed analysis of selected articles within a category. Focus on:

- **Core Change Strategy**
- **Relationship to Change Literature**
- **Ideas about Change**
- **Evidence of Success of Intervention**

Each category completed initially by one researcher and then critiqued by another.

Subcategories



Relationship to Change Literature

- Less than half had any connection to change literature (despite a very liberal definition of "change literature")
- Few commonalities across categories. Two exceptions:
  - **Reflective practice** (Reflective Teachers and Policy)
  - **Departmental and Institutional Cultures** (Policy and Shared Vision)

Curriculum & Pedagogy	Reflective Teachers
5/12 = 42%	**5/12 = 42%**
Policy	Shared Vision
7/13 = 54%	**4/6 = 67%**

Evidence of Success*

- Overall 12/30 (40%) presented at least moderate evidence of success/lack of success.
- Main weaknesses:
  - Reflective Teachers. Often described collecting appropriate data, but reporting was very vague
  - Policy. Often rely on anecdotal evidence

Curriculum & Pedagogy	Reflective Teachers
5/6 = 83% (2 success; 3 No Success)	**1/11 = 9%** (All success)
Policy	**Shared Vision**
3/9 = 33% (1 success; 2 No Success)	**3/4 = 75%** (All success)

*13/43 articles did not present a specific change strategy and are not included in the counts on this slide.

Common Ideas About Change

Six Major Foci

1) **Institutional Structures** (23 articles: all 4 categories)
2) **Individual Faculty** (17 articles: Curriculum & Pedagogy, Reflective Teachers)
3) **Departments as Locus of Change** (8 articles: Reflective Teachers, Policy, Shared Vision)
4) **Diffusion of Innovations** (5 articles, Curriculum & Pedagogy, Reflective Teachers)
5) **Collective Decision-making** (2 articles, Shared Vision)
6) **Multi-level Buy-in** (1 article, Shared Vision)

Institutional Structures

(23 articles: all 4 categories)

[Curriculum & Pedagogy, Reflective Teachers] Barriers to Change:

- Faculty do not have incentive to engage in student-centered instruction
- Implementation of student-centered instruction requires more work from faculty

[Policy] Proactively Stated:

- Institutional leaders need to create a culture that supports teaching excellence
- Faculty instructional practices are shaped by a complex system; the entire system needs to be considered in change efforts

Individual Faculty

(17 articles: Curriculum & Pedagogy, Reflective Teachers)

[Curriculum & Pedagogy] Barriers to change:

- Faculty lack knowledge about student-centered teaching
- Faculty are skeptical of new approaches
- Change takes substantial faculty effort

[Reflective Teachers] Neutral:

- Teaching is context dependent and requires individual faculty adaptation
- Typical faculty development advisor/client approach is not ideal for faculty change

How does this literature review help us?

If trends identified so far continue during further analysis

- - -

Categories of Change Strategies

Two clear criteria allow for meaningful categorization of change strategies into four categories.

1. **What does the change effort intend to directly impact?**
2. **To what extent is the outcome prescribed in advance?**

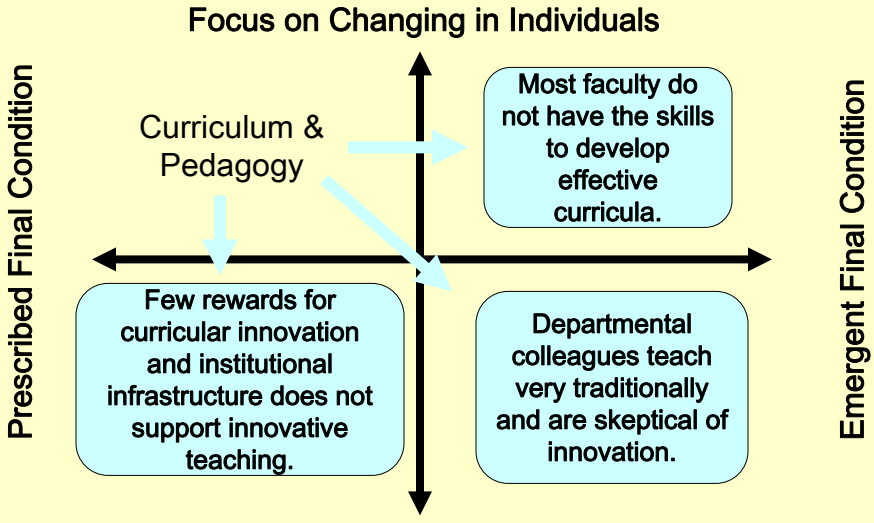
Three Isolated Research Communities

Each has a different and important perspective.

There is little interaction between groups and minimal interaction within groups

(See Beach & Henderson Poster with citation analysis of the articles)

Each change strategy sees areas of influence of other strategies as outside of their control



The person who says it cannot be done should not interrupt the person doing it.

Chinese proverb

Each Group Has Similar Weaknesses

Poor Connection to Change Literature

- 21/43 (49%) had connections to change literature

Little Evidence of Success

- 12/30 (40%) presented at least moderate evidence of success or failure of change strategies
- 7/30 (23%) success, 5/30 (17%) lack of success

Change Strategies are Often not Questioned

- It is often assumed that change strategies are successful (even though evidence is weak or anecdotal)
- If a change strategy does not produce evidence of success, it is often assumed that more time is required:
  - [Curriculum & Pedagogy]"The great ship of teaching and learning does not change direction quickly." (Sharp & McLaughlin, 1997, p. 324)
  - [Reflective Teachers] "This study took place over the course of a year. This was not long enough." (Schneider & Pickett, 2006, p. 264)

Recommendations

We need researchers to:

- Develop change strategies that span categories and research communities
- Develop change theories that are empirically tested and detailed enough to inform action