

Facilitating Change in Undergraduate STEM: The Need to Problematize and Improve Our Approaches to Change

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Abstract

During the last several decades, educational researchers have focused significant attention on the improvement of Science, Technology, Engineering and Mathematics (STEM) subjects. These researchers have identified many shortcomings of "traditional" lecture-based instruction and have developed and demonstrated the efficacy of alternative models of instruction. Yet, many STEM faculty continue to teach traditionally. To better understand this situation we have conducted an interdisciplinary literature review related to change strategies employed in the improvement of undergraduate STEM instruction. Results suggest that there are at least three important groups working towards such change and that approaches to change differ significantly by group. In this session, we will present an overview of the literature review. Participants will engage in discussions about how to combine the strengths of these different approaches towards promoting change as well as how to work towards an interdisciplinary agenda that can lead to improved communication and practice related to promoting change in undergraduate STEM instruction.

Overview

1. Introduction – What is the problem?
2. Change Strategies
 - a) What are some change strategies?
 - b) Categorizing change strategies
 - c) Change strategies found in a literature review
3. Discussion

Collaborators



Yuhfen Lin



**R. Sam
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What's the Problem?

Research suggests that college STEM courses:

- 1) Do not help students develop meaningful understanding of the course content (e.g., Handelsman et al., 2004)**
- 2) Do not help students develop meaningful problem solving skills (e.g., Maloney, 1994)**
- 3) Turn away many capable students who find these courses dull and unwelcoming (e.g., Tobias, 1990)**
- 4) Misrepresent the processes of science (e.g., Halloun and Hestenes, 1998)**

- Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S. M. and Wood, W. B. (2004) Education: Scientific teaching. *Science* 304 (5670), 521-522.
- Maloney, D. (1994) Research on problem solving: Physics. In *Handbook of research on science teaching and learning* (Gabel, D., ed.), MacMillan.
- Tobias, S. (1990) *They're not dumb, they're different: Stalking the second tier*, Research Corporation.
- Halloun, I. and Hestenes, D. (1998) Interpreting VASS dimensions and profiles. *Science & Education* 7 (6), 553-577.

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



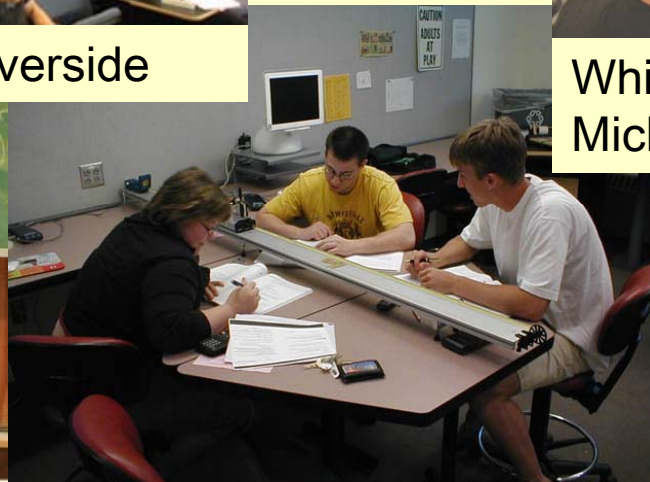
Clicker use at UC Riverside



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

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

• Now all STEM classrooms produce knowledgeable, skilled students who have positive attitudes toward science ...

The Big Question

**How to encourage the spread
of research-based ideas to all
instructors/classrooms?**

Elicitation Activity

What change strategies do you see around you?

How many different change strategies can you think of (relevant to the reform of undergraduate STEM)?

Work individually and compile as many change strategies as you can.

A change strategy is a specific activity or set of activities that is designed to change some aspect of teaching or learning of undergraduate STEM.

Elicitation Activity

What change strategies do you see around you?

How many different change strategies can you think of (relevant to the reform of undergraduate STEM)?

Form a group of 4-5 people (that you don't know well):

- **Introductions:** What experience have you had creating change in undergraduate STEM?
- **Group Product:** Compile a group list of change strategies (can they be categorized?)

A change strategy is a specific activity or set of activities that is designed to change some aspect of teaching or learning of undergraduate STEM.

Why Change Strategies are Important

Evolving Change Strategies 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)

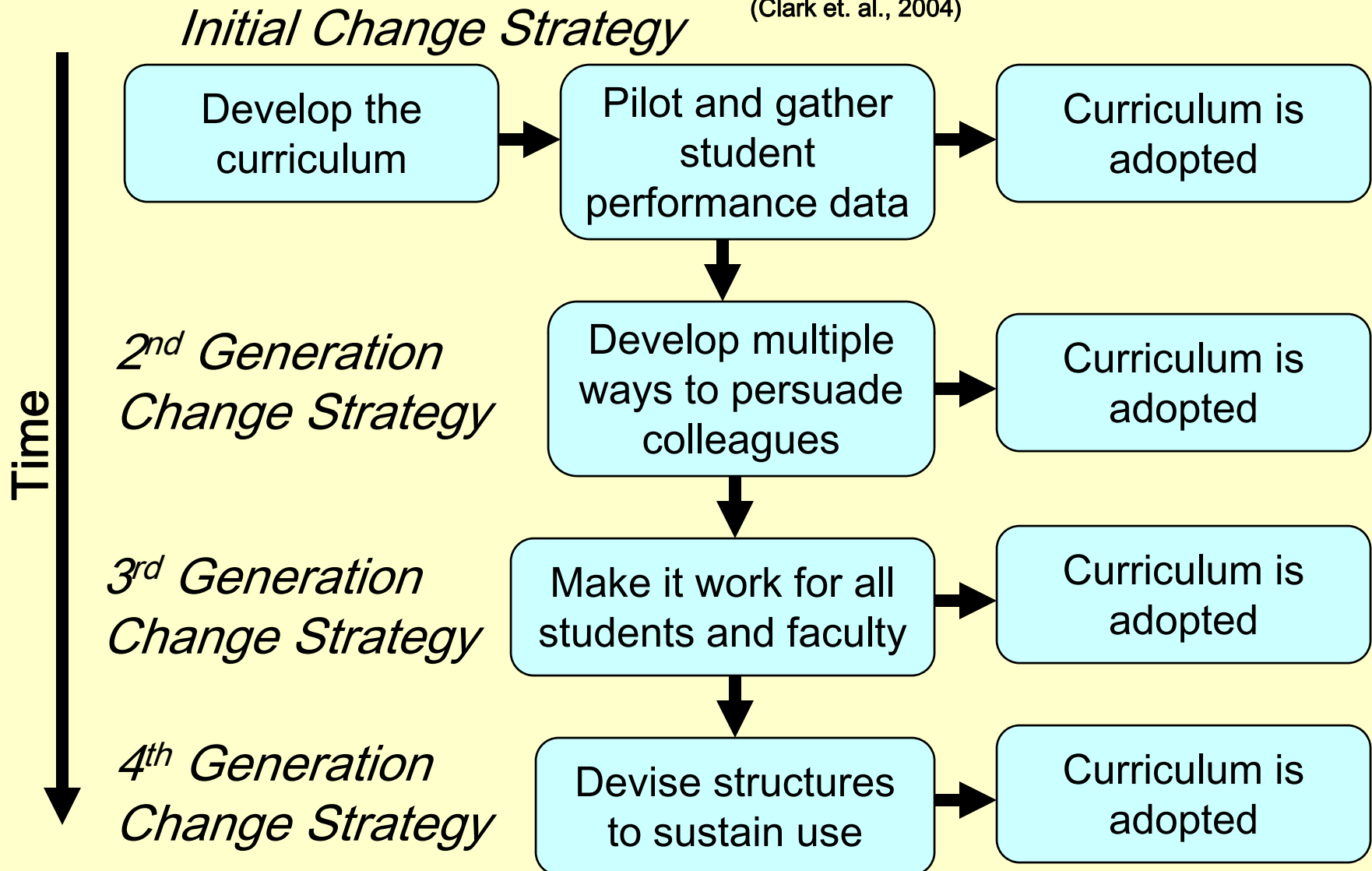


<u>Award Number</u>	<u>Title</u>	<u>NSF Organization</u>	<u>Program(s)</u>	<u>Start Date</u>	<u>Principal Investigator</u>	<u>State</u>	<u>Organization</u>	<u>Awarded Amount to Date</u>
9802942	Foundation Engineering Education Coalition	EEC	ENGINEERING EDUCATION	10/01/1998	Froyd, Jeffrey	TX	Texas Engineering Experiment Station	\$14,191,167.00
9221460	The Foundation Coalition	EEC	ENGINEERING EDUCATION	10/01/1993	Frair, Karen	TX	Texas Engineering Experiment Station	\$14,000,000.00

*C. M. Clark, J. Froyd, P. Merton and J. Richardson, "The evolution of curricular change models within the foundation coalition," Journal of Engineering Education. 93 (1), 37-47 (2004).

Implicit Change Strategies Inferred by Researchers

(Clark et. al., 2004)



Four Categories of Change Strategies developed from an interdisciplinary literature review

For more details:

Henderson, C., Beach, A., Finkelstein, N., & Larson, R. S., (2008, June). Preliminary Categorization of Literature on Promoting Change in Undergraduate STEM. Paper presented at the Facilitating Change in Undergraduate STEM symposium, Augusta, MI.
<<http://www.wmich.edu/science/facilitating-change/PreliminaryCategorization.pdf>>

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>)

Three Groups - One Common Goal

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

The Instruction Paradigm	The Learning Paradigm
<ul style="list-style-type: none"> •Deliver instruction •Achieve access for diverse students •Independent disciplines, departments •Covering material •Grading within classes by instructors •Degree equals accumulated credit hours <li style="text-align: center;">... 	<ul style="list-style-type: none"> •Produce learning •Achieve success for diverse students •Cross discipline/department collaboration •Specified learning results •External evaluations of learning •Degree equals demonstrated knowledge and skills <li style="text-align: center;">...

*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 - One Common Goal

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

The Instruction Paradigm



Traditional Physics class at University of Rochester

The Learning Paradigm



Clicker use at UC Riverside



White boards at Western Michigan University



Workshop Physics Classroom at Dickinson College



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*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*

Current Status:

- **Literature Search**
 - More than 300 relevant journal articles identified
- **Preliminary Analysis**
 - Use 130 articles (randomly selected) to develop four categories of change strategies
 - Use 43 articles (subset of the 130) to identify subcategories and analyze i) strength of data presented and ii) connection to change literature
- **Ongoing Analysis (target completion – Spring 2009)**
 - Complete analysis of remaining articles – modifying categories and coding criteria as necessary
- **Parallel Study (Winter and Spring 2009)**
 - DELPHI (distilling knowledge from a group of experts)

Literature Search

- **Primary Databases: Web of Science, ERIC**
- **Search Terms: change, improvement, reform, teaching, instruction, higher education, college, university, tertiary**
- **Dates: 1995-2008**
- **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

(in original data set)

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)**

Category	Code
Discipline (which disciplinary audience is being spoken to, as defined by the journal)	HER EDR SER: biology, chemistry, engineering, geosciences, math, physics, technology OTHER
Author affiliation	HER EDR SER: biology, chemistry, engineering, geosciences, math, physics, technology

Change Intervention Details			
Source of Change Intervention Details	Specific intervention studied		
Unit of Change Intervention (individual to environment)	Aspects of change intervention(s) inferred		
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

Sample size	One number			
Unit of Sample	Individual Department (or subgroup of department) Institution Extra-Institutional			
Institution Type studied	Research Comprehensive Liberal Arts Community College Mixed Unknown/not applicable			
Significant Findings Claim	Findings			
Study Change – open	Studying Change	Describing Change	Both	Neither
Descriptive Change – open				
Quality Claim Supported by Evidence	Strongly supported	Mixed or support	Weakly supported	
Short summary – open				
Keep/eliminate	Keep for further analysis	Eliminate from further analysis		
Comments	Open			

Categorized along two Important Dimensions

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

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

Categorized along two Important Dimensions

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

Prescribed Final State	Emergent Final State
<p>The desired final state for the individual or environment is known at the beginning of the change process.</p>	<p>The desired final state for the individual or environment is developed as part of the change process.</p>
<p>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.</p>	<p>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.</p>

Four Categories of Change Strategies

Focus on Changing Individuals

Prescribed Final Condition

Tell/teach individuals about new teaching conceptions and/or practices.
 e.g., dissemination (SER, FDR), focused conceptual change (FDR)

Encourage/support individuals to develop new teaching conceptions and/or practices.
 e.g., reflective practice, (FDR), action research (FDR), curriculum development (SER)

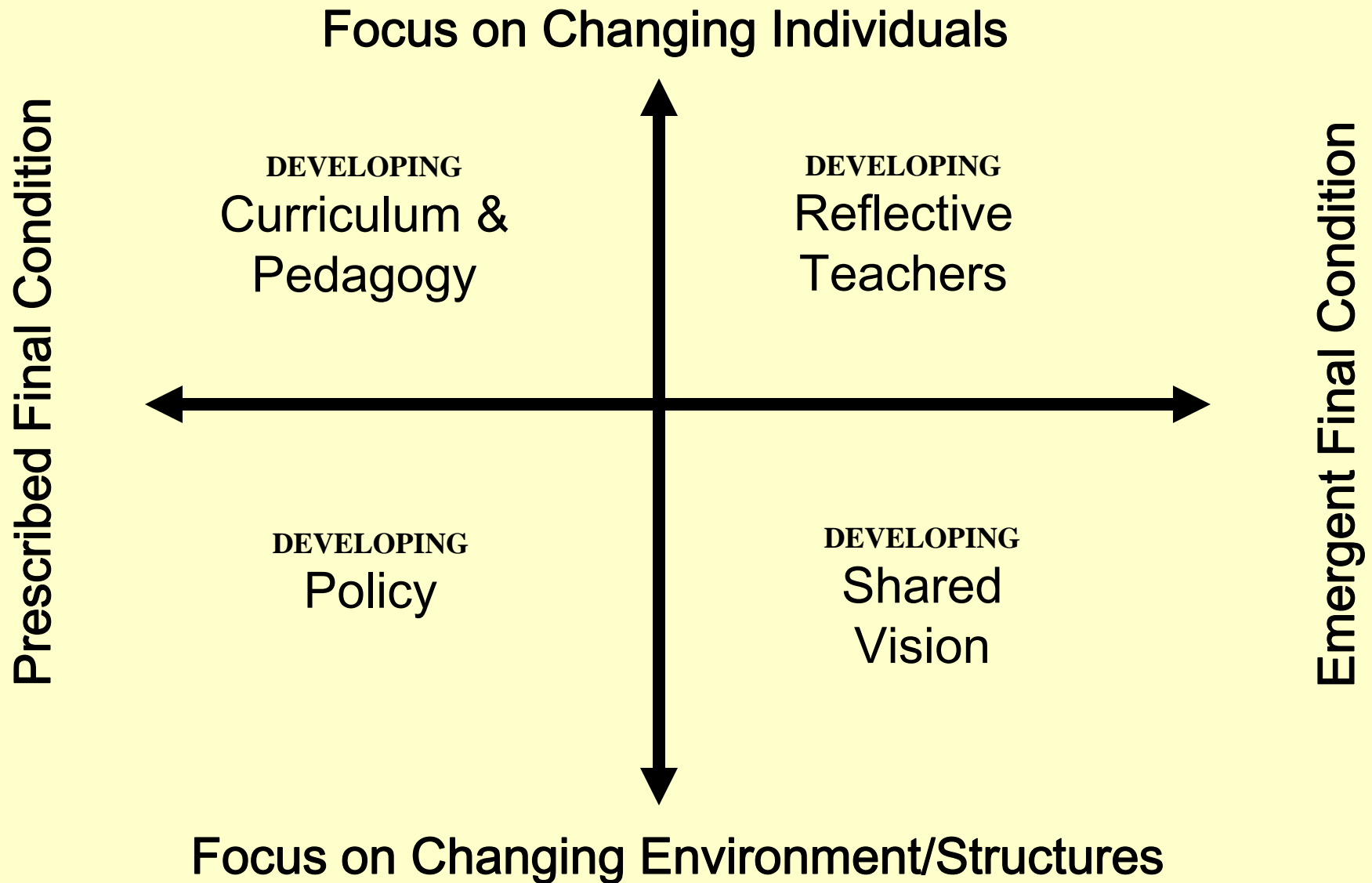
Emergent Final Condition

Develop new environmental features that require/encourage new teaching conceptions and/or practices.
 e.g., policy change (HER), strategic planning (HER)

Empower collective development of environmental features that support new teaching conceptions and/or practices.
 e.g., institutional transformation (HER), learning organizations (HER)

Focus on Changing Environment/Structures

Each Strategy has a Unique Emphasis



Each Strategy has a Unique Change Agent Role

Focus on Changing Individuals

Prescribed Final Condition

Teach/
Tell

Encourage

Direct/
Manage

Empower/
Catalyze

Emergent Final Condition

Focus on Changing Environment/Structures

Application Activity

How do the strategies you thought of earlier relate to the four proposed categories?

Group Activity: Place each of your change strategies in one of the four categories.

Reflection Questions

1. Were some categories more heavily populated than others?
2. Were any categories empty?
3. Did you have strategies that were hard to classify in one of the four categories?

Categorizing Change Strategies from the Published Literature

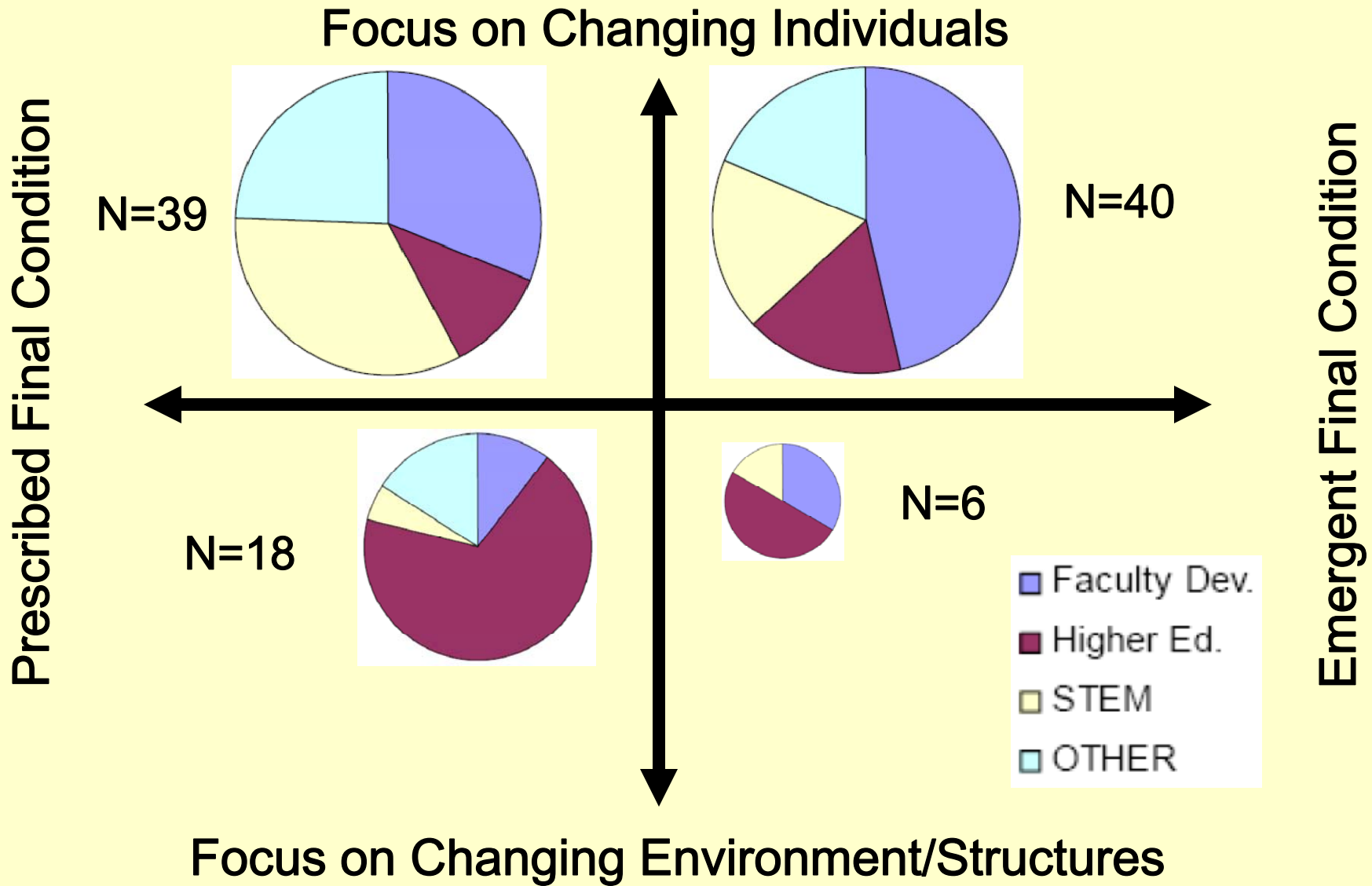
Only Four Articles Could not Be Categorized

<u>Category</u>	<u>Number of Articles</u>	<u>Percentage</u>
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.

Discipline of Authors Align as Expected



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

Focus on Changing Individuals

Prescribed Final Condition

CURRICULUM & PEDAGOGY

- 1) Disseminate Best Practices (N=7)
- 2) Modify Instructor Conceptions (N=4)
- 3) Provide Individualized Diagnosis and Support (N=1)

REFLECTIVE TEACHERS

- 1) Faculty Curriculum Development (N=4)
- 2) Collaborative Action Research (N=3)
- 3) Provide information to help faculty make informed decisions (N=4)
- 4) Departmentally-Based Faculty Development Specialists (N=1)

Emergent Final Condition

POLICY

- 1) System Synchronicity (N=6)
- 2) Institutionalization of quality assurance measures (N=4)
- 3) Directed Incentives (N=3)

SHARED VISION

- 1) Institutional-Level Actions (N=3)
- 2) Externally initiated department level collaboration (N=2)
- 3) Internally initiated department level collaboration (N=1)

Focus on Changing Environment/Structures

Relationship to Change Literature

- Less than half had any connection with any 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 5/12 = 42%	Reflective Teachers 5/12 = 42%
Policy 7/13 = 54%	Shared Vision 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 5/6 = 83% (2 success; 3 No Success)	Reflective Teachers 1/11 = 9% (All success)
Policy 3/9 = 33% (1 success; 2 No Success)	Shared Vision 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.

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)

Three Isolated Research Communities

Each has a different and important perspective.

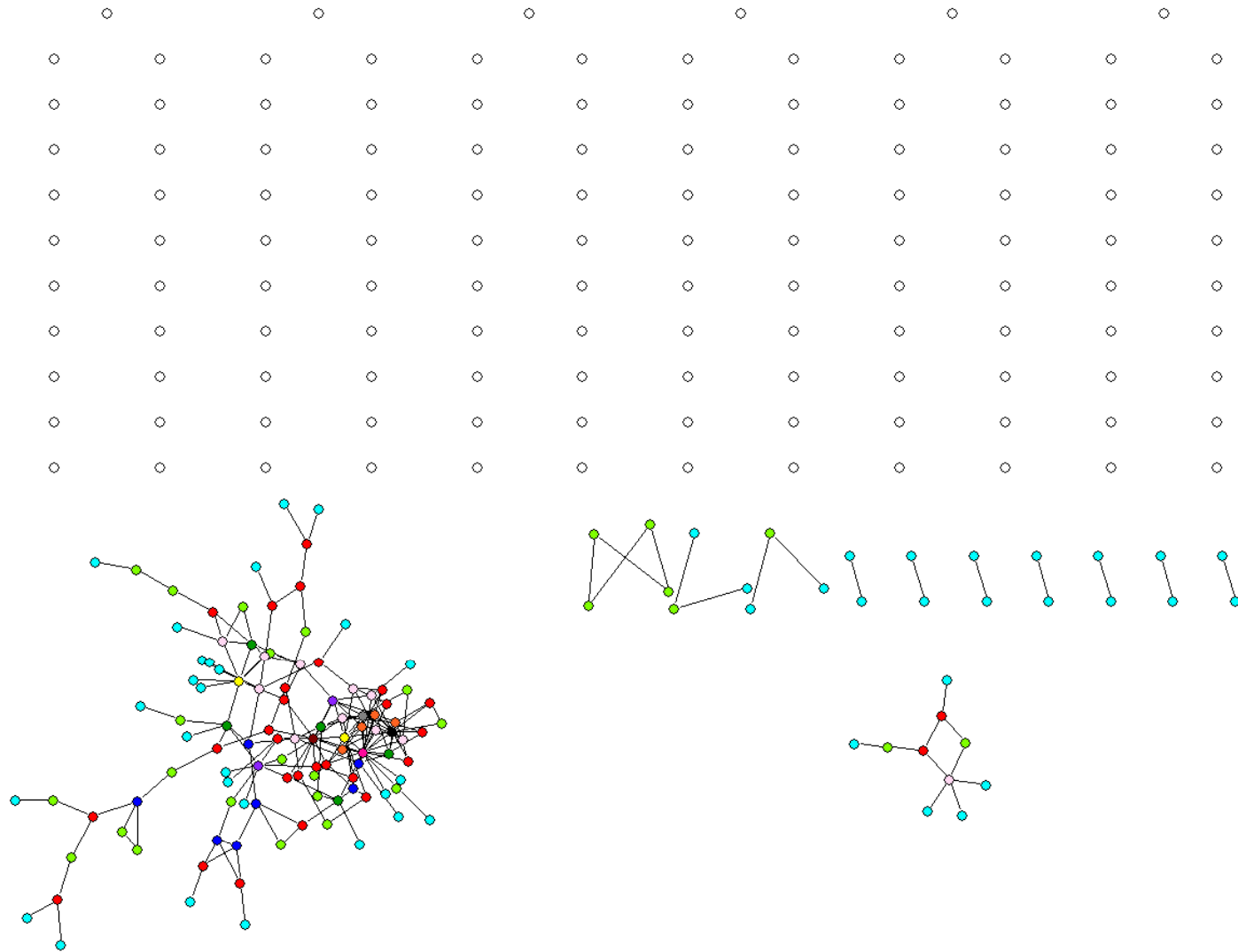
There is little interaction between groups and minimal interaction within groups

(Based on a citation analysis of articles in the data set.)

All 265 Articles with Complete Citation Information

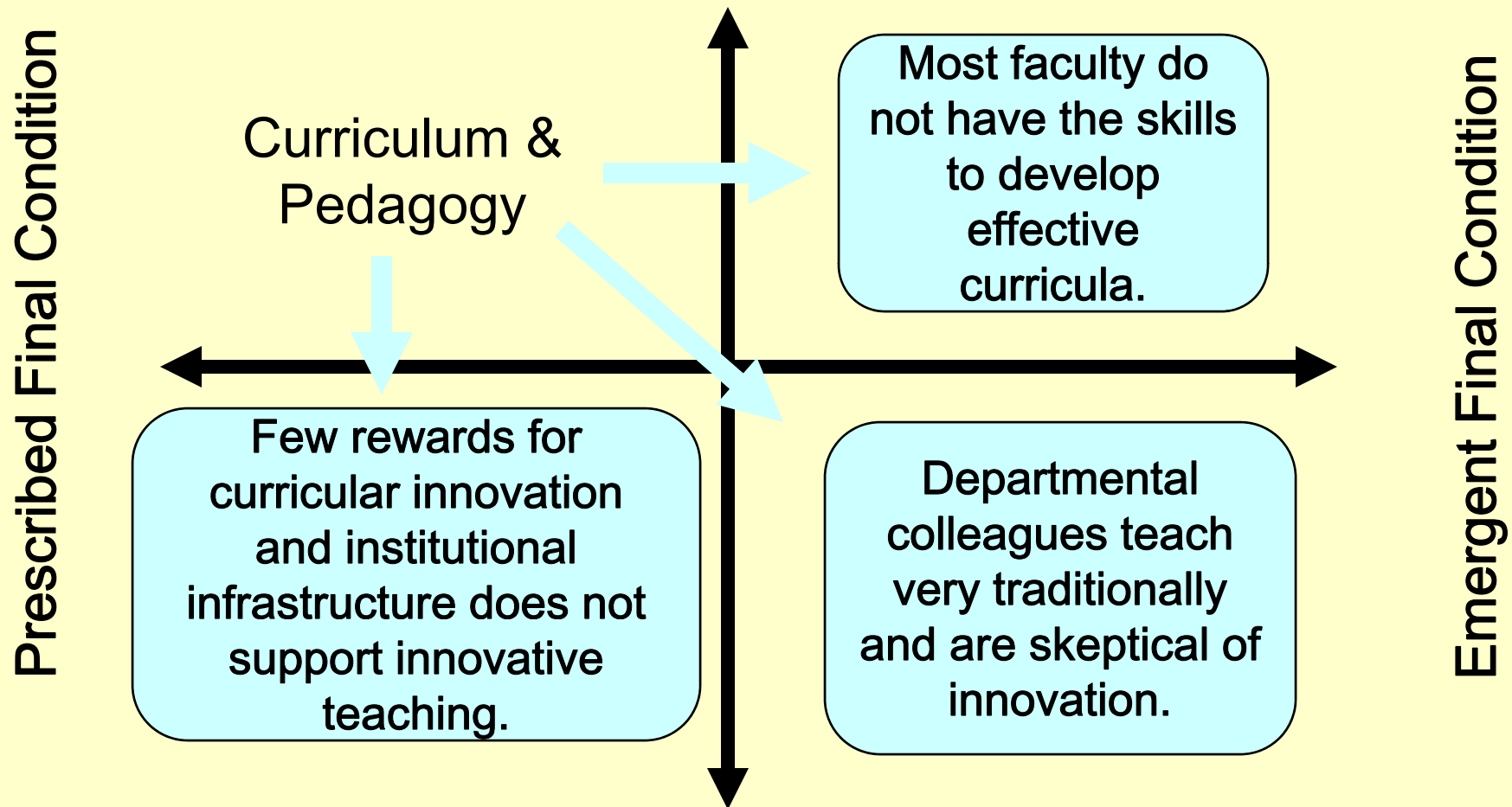
126 articles
(47%) have
no links

50 articles
(18%) have
1 link



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

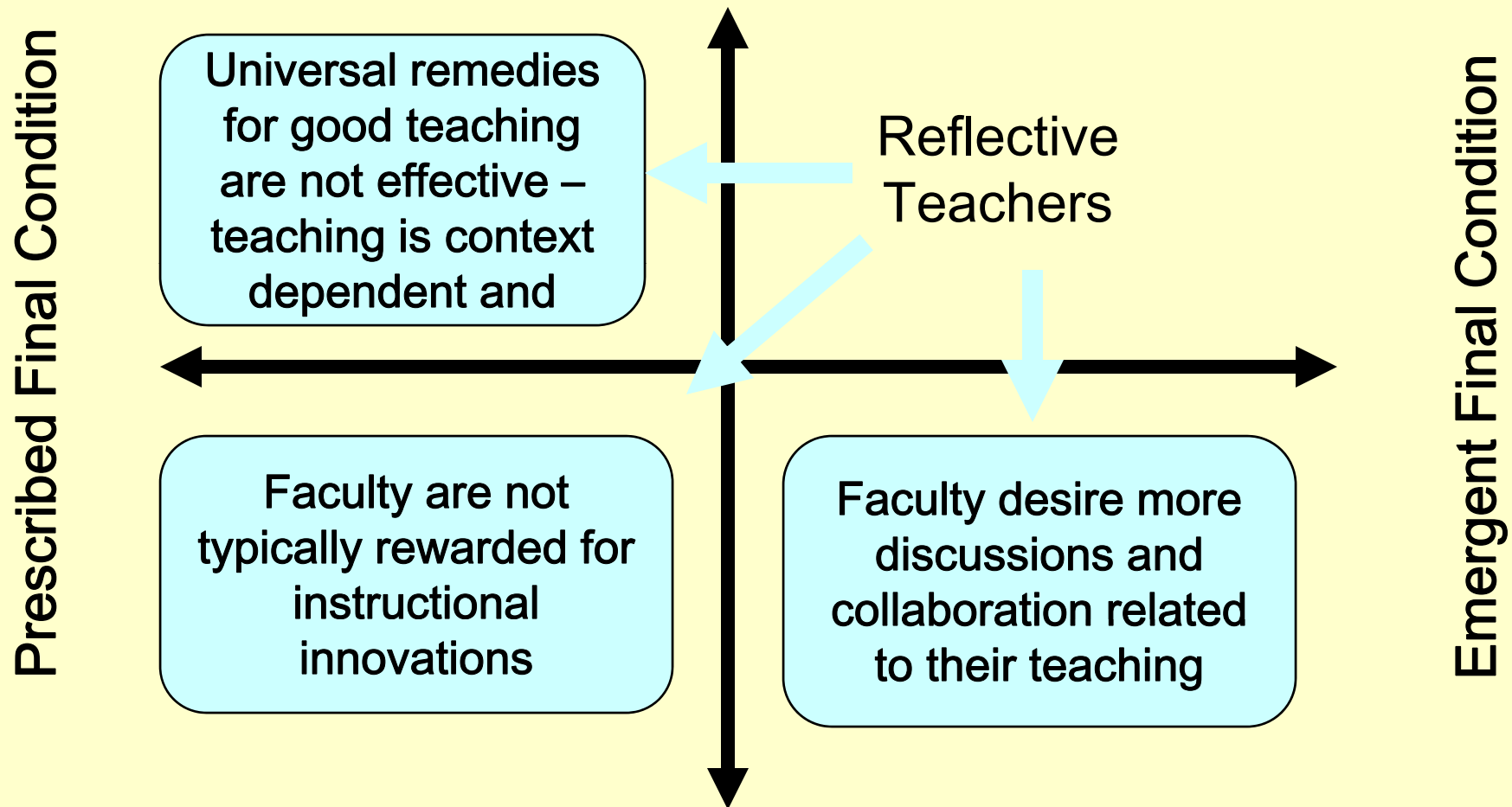
Focus on Changing in Individuals



Focus on Changing in Environment/Structures

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

Focus on Changing in Individuals

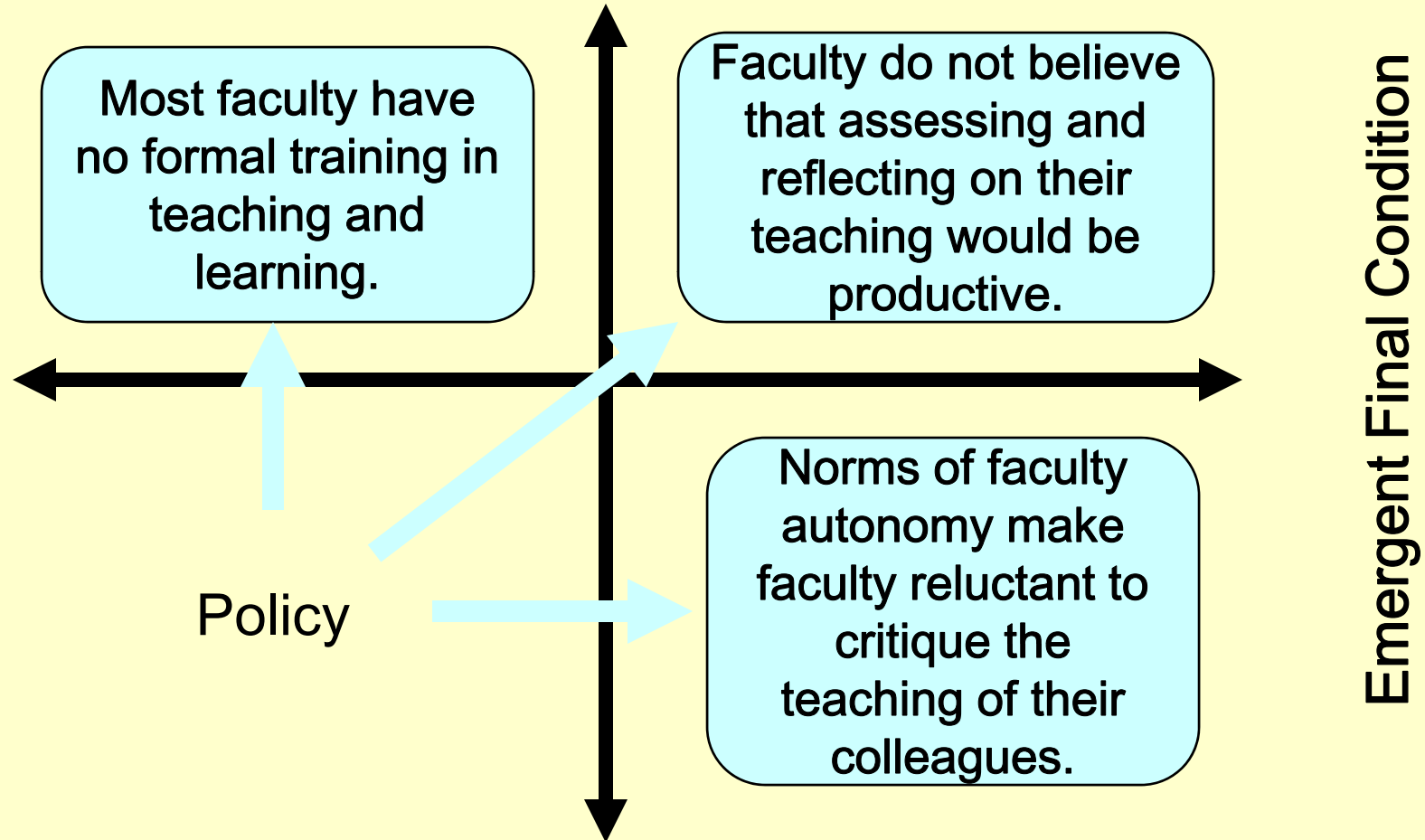


Focus on Changing in Environment/Structures

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

Focus on Changing in Individuals

Prescribed Final Condition



Emergent Final Condition

Focus on Changing in Environment/Structures

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

Chinese proverb

Possible Discussion Questions

- 1. Strategies focused on 'individuals' were four times more common than those focused on 'environments and structures'. Is this a good ratio? Is there an ideal ratio?**
- 2. Is it feasible/desirable to have strategies that span 2, 3, 4 categories?**
- 3. How might we overcome some of the weaknesses of current research on change strategies (i.e., lack of evidence provided, lack of connection to literature)?**
- 4. How might we promote more interdisciplinary work on change strategies?**