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

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http://homepages.wmich.edu/~chenders/
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
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)

• Tobias, S. (1990) They’re not dumb, they’re different: Stalking the second tier, Research Corporation.
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
- Workshop Physics Classroom at Dickinson College
- Traditional Physics class at University of Rochester
- 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)

Implicit Change Strategies Inferred by Researchers
(Clark et. al., 2004)

**Initial Change Strategy**

1. Develop the curriculum
2. Pilot and gather student performance data
3. Curriculum is adopted

**2nd Generation Change Strategy**

1. Develop multiple ways to persuade colleagues
2. Curriculum is adopted

**3rd Generation Change Strategy**

1. Make it work for all students and faculty
2. Curriculum is adopted

**4th Generation Change Strategy**

1. Devise structures to sustain use
2. Curriculum is adopted
Four Categories of Change Strategies developed from an interdisciplinary literature review

For more details:
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)


Faculty Development Researchers (FDR)


Higher Education Researchers (HER)

Three Groups - One Common Goal

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

<table>
<thead>
<tr>
<th>The Instruction Paradigm</th>
<th>The Learning Paradigm</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Deliver instruction</td>
<td>• Produce learning</td>
</tr>
<tr>
<td>• Achieve access for diverse students</td>
<td>• Achieve success for diverse students</td>
</tr>
<tr>
<td>• Independent disciplines, departments</td>
<td>• Cross discipline/department collaboration</td>
</tr>
<tr>
<td>• Covering material</td>
<td>• Specified learning results</td>
</tr>
<tr>
<td>• Grading within classes by instructors</td>
<td>• External evaluations of learning</td>
</tr>
<tr>
<td>• Degree equals accumulated credit hours</td>
<td>• Degree equals demonstrated knowledge and skills</td>
</tr>
</tbody>
</table>

Three Groups - One Common Goal

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</tr>
</tbody>
</table>

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>
</table>
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)

*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: 1995-2008
• 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)
### Change Intervention Details

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

**Develop categorization scheme of change strategies**
Categorized along two Important Dimensions

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

<table>
<thead>
<tr>
<th>Individuals</th>
<th>Environments and Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>The change intends to directly impact personal characteristics of single individuals, such as beliefs, knowledge, behaviors, etc.</td>
<td>The change intends to directly impact extra-individual characteristics of the system such as rules, physical characteristics of the environment, norms, etc.</td>
</tr>
<tr>
<td>Implicit Assumption: Individuals’ actions are primarily influenced by their own volition</td>
<td>Implicit Assumption: Individuals’ actions are primarily influenced by external environments</td>
</tr>
</tbody>
</table>
Categorized along two Important Dimensions

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

<table>
<thead>
<tr>
<th>Prescribed Final State</th>
<th>Emergent Final State</th>
</tr>
</thead>
<tbody>
<tr>
<td>The desired final state for the individual or environment is known at the beginning of the change process.</td>
<td>The desired final state for the individual or environment is developed as part of the change process.</td>
</tr>
<tr>
<td>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.</td>
<td>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.</td>
</tr>
</tbody>
</table>
Four Categories of Change Strategies

Focus on Changing Individuals

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)

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

Focus on Changing Individuals

Prescribed Final Condition

DEVELOPING Curriculum & Pedagogy

DEVELOPING Reflective Teachers

DEVELOPING Policy

DEVELOPING Shared Vision

Focus on Changing Environment/Structures
Each Strategy has a Unique Change Agent Role

- Focus on Changing Individuals
  - Teach/Tell
  - Encourage

- Focus on Changing Environment/Structures
  - Direct/Manage
  - Empower/Catalyze

Prescribed Final Condition

Emergent Final Condition
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

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Articles</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum &amp; Pedagogy</td>
<td>39</td>
<td>30.0%</td>
</tr>
<tr>
<td>Teachers</td>
<td>40</td>
<td>30.8%</td>
</tr>
<tr>
<td>Policy</td>
<td>18</td>
<td>13.8%</td>
</tr>
<tr>
<td>Shared Vision</td>
<td>6</td>
<td>4.6%</td>
</tr>
<tr>
<td>Not Categorizable</td>
<td>4</td>
<td>3.1%</td>
</tr>
<tr>
<td>Background</td>
<td>9</td>
<td>6.9%</td>
</tr>
<tr>
<td>Eliminate</td>
<td>14</td>
<td>10.8%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>130</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

**All Review Articles**

Discipline of Authors Align as Expected

Focus on Changing Individuals

Prescribed Final Condition

N=39

Emergent Final Condition

N=40

Focus on Changing Environment/Structures

N=18

N=6

- Faculty Dev.
- Higher Ed.
- STEM
- OTHER
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.
Focus on Changing Individuals

**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)

**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)

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<th>Category</th>
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<tr>
<td>Curriculum &amp; Pedagogy</td>
<td>5/12 = 42%</td>
</tr>
<tr>
<td>Reflective Teachers</td>
<td>5/12 = 42%</td>
</tr>
<tr>
<td>Policy</td>
<td>7/13 = 54%</td>
</tr>
<tr>
<td>Shared Vision</td>
<td>4/6 = 67%</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th>Curriculum &amp; Pedagogy</th>
<th>Reflective Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy</td>
<td>5/6 = 83%</td>
<td>1/11 = 9%</td>
</tr>
<tr>
<td></td>
<td>(2 success; 3 No Success)</td>
<td>(All success)</td>
</tr>
<tr>
<td>Shared Vision</td>
<td>3/9 = 33%</td>
<td>3/4 = 75%</td>
</tr>
<tr>
<td></td>
<td>(1 success; 2 No Success)</td>
<td>(All success)</td>
</tr>
</tbody>
</table>

*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
Articles in the largest cluster with three or more links (N=57)
Each change strategy sees areas of influence of other strategies as outside of their control.

**Focus on Changing in Individuals**

- **Curriculum & Pedagogy**
  - Few rewards for curricular innovation and institutional infrastructure does not support innovative teaching.
  - Most faculty do not have the skills to develop effective curricula.

- **Focus on Changing in Environment/Structures**
  - Departmental colleagues teach very traditionally and are skeptical of innovation.

**Prescribed Final Condition**

**Emergent Final Condition**
Each change strategy sees areas of influence of other strategies as outside of their control.

Focus on Changing in Individuals

- Universal remedies for good teaching are not effective – teaching is context dependent and
- Faculty are not typically rewarded for instructional innovations

Reflective Teachers

- Faculty desire more discussions and collaboration related to their teaching

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

Most faculty have no formal training in teaching and learning.

Faculty do not believe that assessing and reflecting on their teaching would be productive.

Emergent Final Condition

Policy

Norms of faculty autonomy make faculty reluctant to critique the teaching of their colleagues.

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?