

FOUR CATEGORIES OF CHANGE STRATEGIES FOR TRANSFORMING UNDERGRADUATE INSTRUCTION

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Abstract

Although decades of research have identified effective instructional practices for improving science instruction in colleges and universities, these practices are not widely implemented. Scholars in several distinct fields are interested in promoting these practices and have engaged in research on pedagogical change. This chapter presents the initial results of a comprehensive literature review. We undertook an examination of 130 randomly chosen journal articles from a set of 295 that were identified as addressing change in the instructional practices of science, technology, engineering, and mathematics (STEM) faculty. Four core categories of change strategies were identified based on this literature: Disseminating Curriculum and Pedagogy, Developing Reflective Teachers, Developing Policy, and Developing Shared Vision. The use of particular types of change strategies differs by field in important ways and has implications for the success of the change effort. Common weaknesses in the body of literature are also identified, and include a lack of connection to other change literature and a lack of presentation of data to support claims of success or failure of change strategies.

Keywords: educational change, educational reform, STEM, college, undergraduate

I. Introduction

Recent decades have seen increasing calls for fundamental change in the teaching of Science, Technology, Engineering, and Mathematics (STEM). National commissions, state panels, university administrators, and individual researchers have expressed concern that college-level STEM instructors frequently use outdated and ineffective instructional practices (e.g., National Research Council, 2003, 2007). The conversation has been dominated by the perceived need to fundamentally shift the entire undergraduate education paradigm from instructional- or teacher-centered to learning- or student-centered (e.g., Barr & Tagg, 1995). These concerns have led to significant expenditures of time and money on research to improve teaching and learning. Yet, these efforts have met with only modest success (e.g., Bok, 2006; Boyer Commission on Undergraduates in the Research Universities, 1998; Handelsman, et al., 2004; Kezar, 2001; Seymour, 2001).

This project began with the assumption that at least three distinct research communities are involved in the endeavor to improve undergraduate instruction in STEM disciplines. *Disciplinary-based STEM Education Researchers* (SER) are typically situated in STEM-related departments, frequently in a college of arts and sciences, but sometimes in a college of engineering or as disciplinary STEM specialists in a college of education. SER researchers are particularly interested in studying student learning within their discipline and developing discipline-specific curricular materials to improve this learning. *Faculty Development Researchers* (FDR) are typically situated in centers for teaching and learning. The mission of these centers is commonly to provide professional development for all faculty at an institution. Therefore, FDR researchers often focus on providing faculty with more general pedagogical skills or motivation and tools for self-improvement. *Higher Education Researchers* (HER) are

typically situated in a departments of educational leadership in a college of education and, sometimes, in university administration. HER researchers often study how cultural norms, organizational structures, and state and national environments and policy influence higher education practices. In contrast to the other groups, HER frequently focus their research beyond individuals to the institutional or national level.

In addition to unique disciplinary interests and histories, each of these groups has its own distinct professional societies, journals, and disciplinary norms. The work of these groups is deeply complementary, and one would assume that these three research communities regularly share their findings with each other, since doing so would yield better understanding and theory regarding change in teaching and learning. Our initial analysis, however, suggests that such sharing among these scholarly communities is rare. For example, three recent overviews of change processes and strategies, one from the SER tradition (Seymour, 2001) one from the FDR tradition (Emerson & Mosteller, 2000) and one from the HER tradition (Kezar, 2001), do not contain a single common reference or citation.

We see a strong need for interdisciplinary research on STEM instructional improvement that draws from the knowledge and experiences of all of these research communities, and from the field of organizational change. We believe that interdisciplinary research must be supported by a better understanding of how the research literatures of each community align and can be integrated to present the most promising change *strategies* (coherent set of improvement approaches), and change *theories* (systematic, formalized expressions about how change occurs). We therefore have had two foci in our work. First, and primarily, we were drawn to published studies of change interventions. We wanted to know what kinds of strategies were being used to change STEM education and/or instruction in higher education. Second, we wanted to explore how authors framed their study of interventions – to gauge, if you will, the extent to which the research on interventions is already multidisciplinary and the extent to which it draws from theories of change.

The research questions that guided this initial review of the literature are:

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?

II. Methods

Identifying articles

The goal of the literature search was to identify journal articles that describe efforts by change agents to improve instructional practices used in undergraduate STEM education.¹ Articles were selected through a succession of inclusion and exclusion criteria. First, the most productive indexes were identified for initial searching: Web of Science and ERIC. We set the window for inclusion at 1995 to 2008. Multiple scans of the literature indexed in these databases were undertaken with different combinations of terms related to “change”, “teaching”, “instruction”, “improvement”, “higher education”, “college”, and “university”. Abstracts were used to exclude articles that did not meet the content criteria. Additionally, we specifically examined the journals that appeared to produce the greatest number of articles that fit our inclusion criteria to ensure that we had gleaned all the relevant literature they offered. We also examined the reference lists of the articles identified as most closely fitting our inclusion criteria, to find additional relevant articles, especially those published prior to 1995. The final database used for this analysis contains 295 journal articles.

Analysis procedures

For the initial review presented here, we undertook an examination of 130 randomly chosen journal articles from the set of 295 identified. We used an inductive analysis process that involved reading and initial coding of articles (by overlapping pairs of research team members) to identify the research community of the authors, the focus of the change approach, the “level” at which the change described is being aimed (individual, group, institutional, extra-institutional), the apparent role of the change agent, if discernable, and the degree of specificity of the outcome intended. (See Appendix A for the coding sheet used.) The research team discussed what we had learned from our initial reading of the chosen articles, ways to define the patterns and themes we saw emerging from the articles, and how we saw those patterns coming together to form potentially useful categories. From these initial coding approaches emerged two guiding questions that, when combined, form four categories of change strategies. We then re-reviewed the 130 articles and placed them within the categories developed.

In a second analysis round, we selected 10 articles from each of the four categories for more detailed qualitative examination. We looked for the core change idea(s) either explicitly or implicitly evident in the change process described in the articles, the degree to which the authors grounded their work in established change literature, the evidence authors present to support their change strategies, and ideas about change expressed by the authors. Data were collected in the form of quotes, bullet lists, and synopses and arranged into a narrative summary of each article that could be analyzed for patterns. One member of the research team completed the first analysis of the articles within a particular category. This work was then examined and modified by another member of the research team, often with significant discussion. As a result of this

¹ By using the phrase “efforts by change agents,” we intend to exclude all articles related to descriptions of new teaching ideas developed by instructors with no emphasis on the dissemination of these ideas. There has been much work published in this area and descriptions of “best practices” are widely available. We wish to determine, in part, how this work can be used to impact teaching practices beyond the developers.

closer analysis, several articles were moved from their initial categories. A total of 43 articles were ultimately analyzed in this second round.

We consider the results presented in this chapter to be preliminary because they are based on an analysis of only 130/295 (44%) of articles in our database, of which only 43/295 (15%) were further analyzed for subcategories and themes. Subsequent analysis on the broader data set appears to corroborate findings described below.

III. Results

A. Two key categorization criteria

The four proposed categories of change strategies are based on the answers to two fundamental questions that were arrived at through multiple rounds of initial coding and discussion. The first question identifies the locus of change as either individuals or environments and structures. The second question identifies the desired outcomes as either prescribed or emergent. Tables 1 and 2 present the definitions we developed for each response, and the underlying assumption about change that we saw driving each definition.

Table 1: *First Categorization Criteria - Individuals vs. Environments.*

Question: What is the primary aspect of the system that the change approach seeks to directly impact?	
<u>Individuals</u>	<u>Environments and Structures</u>
<p>Definition: The change intends to directly impact personal characteristics of single individuals, such as beliefs, knowledge, behaviors, etc.</p>	<p>Definition: The change intends to directly impact characteristics of the system that are external to single individuals, such as rules, physical characteristics of the environment (e.g., room layout, technology), 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>

Table 2: *Second Categorization Criteria - Prescribed vs. Emergent*

Question: To what extent is the intended outcome for the individual or environment known in advance?	
<u>Prescribed</u>	<u>Emergent</u>
Definition: The desired final state for the individual or environment is known at the beginning of the change process.	Definition: 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 (i.e., 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.

B. Four core categories of change strategies

Based on the possible combinations of responses to the two guiding questions, we developed a four-square typology of change strategies. The categories are depicted in Table 3 and described in the following four sections.

Table 3: *Four-Square Typology of Change Categories*

	Aspect of System to Be changed: Individuals		
Intended Outcome: Prescribed	<p>I. Disseminating: CURRICULUM & PEDAGOGY</p> <p>Change Process: Tell/Teach individuals about new teaching conceptions and/or practices and encourage use.</p> <p>Examples: dissemination/training (SER, FDR), focused conceptual change (FDR)</p>	<p>II. Developing: REFLECTIVE TEACHERS</p> <p>Change Process: Encourage/Support individuals to develop new teaching conceptions and/or practices.</p> <p>Examples: reflective practice (FDR), curriculum development (SER) , action research</p>	Intended Outcome: Emergent
	<p>III. Developing: POLICY</p> <p>Change Process: Develop new environmental features that Require/Encourage new teaching conceptions and/or practices.</p> <p>Examples: policy change (HER), strategic planning (HER)</p>	<p>IV. Developing: SHARED VISION</p> <p>Change Process: Empower/Support stakeholders to collectively develop new environmental features that support new teaching conceptions and/or practices.</p> <p>Examples: institutional transformation (HER), learning organizations (HER)</p>	
	Aspect of System to Be changed: Environments and Structures		

Of the 130 articles randomly chosen for initial analysis, we determined that 14 were not relevant to our analysis and removed them. Several were curriculum development articles focused only on student learning outcomes (one of our exclusionary criteria) or were focused on K-12 education. Nine articles were classified “background” reading. They do not directly fit the search criteria, but are relevant in some way and are particularly well-written or comprehensive. Four articles clearly spanned more than one category, with multiple change foci or combination of emergent outcomes. All four of these were review articles that did not present and discuss specific change interventions, but discussed a range of issues regarding instructional change. We keep careful track of these articles during further analysis. Of the remaining 111 articles, there was an almost even split between the number that fell into either the *Curriculum & Pedagogy* and *Reflective Teachers* categories, and far fewer that fit into the *Policy* or *Shared Vision* categories. These numbers are summarized in Table 4 and reflect the adjustments we made in categorization while undertaking the second round of analysis.

Table 4: Breakdown of Category Placement

Category	Number of Articles in larger analysis set	Percentage of Articles	Number of articles in more detailed analysis set
Curriculum & Pedagogy	39	30.0%	12
Reflective Teachers	40	30.8	12
Policy	18	13.8	13
Shared Vision	6	4.6	6
Not Categorizable	4	3.1	
Background	9	6.9	
Eliminate	14	10.8	
Total	130	100	43

We wanted to know how the three research communities were represented by the articles we placed within each category in the four-square typology. Figure 1 below represents in pie charts the disciplines of the authors, coded FDR, HER, SER or Other. The Other category encompasses authors from disciplines that were not part of our initial expectations of disciplinary communities. Often these authors are from social science disciplines such as psychology or sociology and often, but not always, they are writing jointly with an author from one of the other three disciplines. As can be seen from the figure, authors designated HER dominate the Policy and Shared Vision categories. SER authors are the largest group in the Curriculum & Pedagogy category, and FDR authors have the largest share of articles in the Reflective Teachers category.

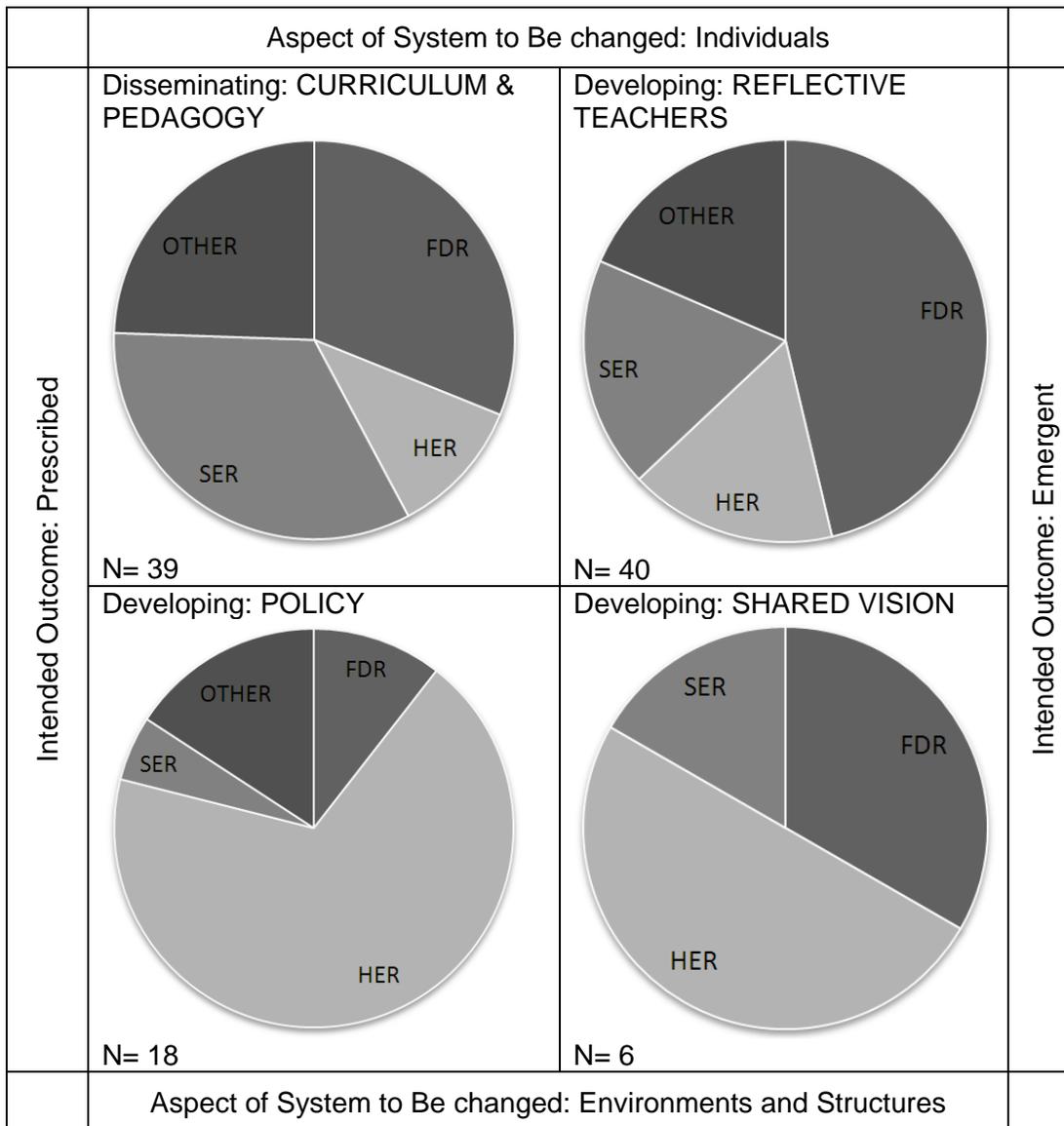


Figure 1. Representation of Research Communities in Change Categories

The next four sections describe in detail the four categories developed through initial coding and summarize roughly ten articles apiece that fall within each subcategory. We begin each section by describing the nature of the category and the subcategories of interventions we found within this broader category of change from the two rounds of analysis. Our emphasis then shifts to examine how the authors of these manuscripts frame how they study these interventions. How the authors frame their studies can influence how others study and implement change. Thus, we list ideas about change that are found in more than one article as well as the level of evidence presented in each article to support the proposed intervention. Note that the final number of

articles in each category is not even because some were moved during the more detailed phase of analysis.

Category I. Individual/Prescribed – Focus on disseminating curriculum and pedagogy

This category is defined by its intersection of individual focus and prescribed outcomes. The emphasis of this type of intervention is on communicating the change agent's vision of good teaching to individual instructors. Thus, the prominent aspects of the interventions are the curricular materials, instructional strategy, and/or associated instructor knowledge/conceptions. Change agents have a particular instructional strategy or conception about teaching and learning that they hope individual instructors will adopt. Change agents typically inform instructors about the target instructional strategy or conception and provide motivation for the instructor to adopt it. Varying levels of support are offered to assist in adoption.

The following subcategories were identified within this category:

- 1) Disseminate Best Practices (7 articles). Change agent seeks to disseminate (and, perhaps develop or compile) a set of “best practices” instructional strategies or materials.
- 2) Modify Instructor Conceptions (4 articles). Change agent seeks to promote adoption among faculty of a set of instructional conceptions that are compatible with “best practices.”
- 3) Provide Individualized Diagnosis and Support (1 article). Change agent works with individual instructors to identify instructional difficulties and improve them.

Common change statements

The articles in this category express some common ideas about change in faculty instructional practices. Below are ideas expressed by more than one article:

- Faculty do not have incentive to engage in student-centered instruction (Gibbs & Coffey, 2004; Hativa, 1995; Luft, et al., 2004; Miller, et al., 2000; Walczyk & Ramsey (2003) ; Weiss, et al., 2004).
- Instructors typically lack knowledge about student-centered instruction (Hanson & Moser, 2003; Hativa, 1995; Luft, et al., 2004; Miller, et al., 2000; Winter, et al., 2001; Yarnall, et al., 2007).
- Faculty are happy with traditional instruction and are skeptical that other methods are superior (Miller, et al., 2000; Trigwell, et al., 1994; Van Driel, et al., 1997; Winter et al., 2001; Yarnall, et al., 2007).
- Institutional support (top-down or external) is important for change to occur (Hativa, 1995; Miller, et al., 2000; Sharp & McLaughlin, 1997; Weiss, et al., 2004).
- There is pressure to conform to teacher-focused instructional conventions used by colleagues (Gibbs & Coffey, 2004; Van Driel, et al., 1997).
- “Cascade Effect” – It is expected that instructors who are at the receiving end of dissemination programs will further disseminate these products to their colleagues (Sharp & McLaughlin, 1997; Walczyk & Ramsey, 2003). This doesn't happen (Sharp & McLaughlin, 1997).

- Change takes time – we need to be patient (Miller et al., 2000; Sharp & McLaughlin, 1997).
- Implementation of student-centered instruction requires more work from faculty than teaching traditionally (Hanson & Moser, 2003; Miller, et al., 2000).

Evidence and Success of change interventions

Five of the 12 articles in this category presented enough evidence to be judged at least moderately convincing. Of these, two point to the success of the intervention and three point to the lack of success of the intervention. One article studied an intervention, but provided little or no evidence of success. Six articles in this category either did not study the effects of a change strategy or did not study a change strategy.

Of the articles pointing to success, Hativa (1995) reported that 75% of faculty participants made changes in their teaching practices as a result of the intervention, and 11 of 20 faculty participants (55%) saw improved student ratings of their teaching. Of those articles reporting a lack of success of the intervention studied, Weiss et al. (2004) found that the interaction of the instructor with the reform collaborative did not result in the desired changes in her beliefs about teaching and learning nor in a fundamental change in her teaching practices. As an example of an article that offered little or no evidence of change, Hanson & Moser (2003), write about a curriculum module development and dissemination project; however, they did not document the extent of curriculum module use. Evidence presented suggests that, when modules are used, they are used by faculty mainly as a source of ideas (rather than as a curriculum to be followed). It is not clear what, if any, instructional changes resulted from these ideas.

Category II. Individual/Emergent—Focus on developing reflective teachers

This category is defined by its intersection of individual focus and emergent outcomes. The focus of this type of intervention is on encouraging instructors to use their own knowledge/experience/skill to improve their instructional practices. Information about various instructional strategies and materials may be provided, but this is not the main focus of the intervention. The change agent typically has a particular activity (e.g., action research, learning communities) that he or she hopes instructors or groups of instructors will engage in to develop new (at least to them) instructional strategies or conceptions. Varying levels of change agent support and control of the process are provided. The literature base that appeared most influential for articles in this category centers on reflective practice and action research and the primary role of the change agent is that of encouragement. The articles in group 3 (below, where change agents present a variety of options to faculty) are closest to the prescriptive focus of the curriculum/pedagogy category. The difference here is that faculty are seen as being in a strong position to choose appropriately.

The following subcategories were identified within this category:

- 1) Support for Individual Curriculum Development (4 articles) – Individuals reflect on teaching and develop, test, and refine new instructional ideas (sometimes, formally through action research cycles, other times less formally).

2) Collaborative Action Research (3 articles) – Teams of faculty (often from multiple disciplines) work together to develop, test, and refine aspects of a particular course.

3) Provide information to help faculty make informed decisions (4 articles) – An external change agent introduces faculty to a wide set of new pedagogical ideas and encourages faculty to use their expertise to reflect on and adapt the ideas to their own teaching situations. (Unlike the action research subcategories above, in this subcategory, there is no explicit action-reflection phase.)

4) Departmentally-Based Faculty Development Specialists (1 article) – A faculty member within an academic department or unit is identified as a faculty development associate and given release time to identify local faculty development needs and implement appropriate programs.

Common change statements

The articles in this category express some common ideas about change in faculty instructional practices. Below are ideas expressed by more than one article.

- Universal remedies for good teaching are not effective – teaching is context dependent and adaptation is always necessary (Candy & Borthwick, 1994; Kember & McKay, 1999; Krockover, et al., 2002; Malicky, et al., 2007; Wildman et al., 2000).
- Typical role is of advisor/client and a more even relationship where each respects the expertise of the other is needed (Candy & Borthwick, 1994; Howland & Wedman, 2004; Kember & McKay, 1999; Wildman, et al., 2000).
- Faculty are not typically rewarded for instructional innovations (Fruyer, 1999; Kember & McKay, 1999; Krockover, et al., 2002; Romano, et al., 2004).
- Substantial time and effort are required for instructional change (Howland & Wedman, 2004; Krockover, et al., 2002; Malicky, et al., 2007; Schneider & Pickett, 2006; Stevenson, et al., 2005).
- Changes initiated by individual faculty can spread to others in the department once evidence is collected to convince these colleagues (Kember & McKay, 1999; Krockover, et al., 2002).
- Change cannot be initiated from outside a department (Candy & Borthwick, 1994; Kember & McKay, 1999).

Success of change interventions

Eleven of the 12 articles in this category described the outcomes of a specific change intervention. Only one of the 11 articles presented enough evidence to be judged at least moderately convincing. Six articles presented weak evidence of success and four provided little to no evidence.

The article that we judged as presenting at least moderate evidence of success was that by Kember & McKay (1996). The action research project described in the intervention was initiated by one faculty member and eventually (over a 5 year period) expanded to produce major curricular change within the department. Of those articles providing weak evidence of success, Romano, et al. (2004), in a study of a year-long program, found that 80% of participants reported

changes in the amount of in-class interaction with students and changes in course syllabus. The extent of these changes is not clear, nor is their nature. As an example of an article that offered little or no evidence of success Stevenson, et al. (2005) report faculty satisfaction with and value of training workshops, but report no evidence of meaningful instructional change.

Category III. Environments/Prescribed – Focus on developing policy

This category is defined by its intersection of focus on environment/structures and prescribed outcomes. The emphasis of this type of intervention is on developing appropriate environments (e.g., rules, reward systems, reporting requirements, investments in support structures) to facilitate instructors engaging in specific or desired activities. The change agents have a particular vision towards which they wish to encourage instructors to work. Typically this means that an instructor adopts a particular activity, strategy, conception, or outcome. Whereas interventions that focus on individuals use internal motivation as the primary mechanism for change, here significant external incentives or requirements are used. The literature base most often invoked in these articles includes management theory, leadership, and organizational culture. The primary change agent role identified within these articles is directing, leading, or managing.

The following subcategories were identified within this category:

- 1) System Synchronicity (6 articles). Top-down change initiatives must make sure that they are not in conflict with cultural and operational norms at lower levels of the system. Power alone is insufficient; the change has to be consistent with key aspects of the system.
- 2) Institutionalization of quality assurance measures (4 articles). Departments, colleges or university implement measures of effectiveness around instructional practices.
- 3) Directed Incentives (3 articles). Institutions can transform their teaching through directed initiatives from those in power. Presidents, chairs, and deans can influence change by offering incentives or recognition.

Common change statements

The articles in this category express some common ideas about change in faculty instructional practices. Below are ideas expressed by more than one article:

- Institutional leaders need to create a culture that supports teaching excellence (Austin, et al., 1997; Hannan, 2005; Johnson, 2006; Major and Palmer, 2006; Massey et al., 1994; Wright et al., 1999).
- Policies that seek uniformity and deter individualized solutions are not likely to be effective in promoting change (Colbeck, 2002; Hannan, 2005; Major & Palmer, 2006; McDaniel, et al., 2000; Skoldberg, 1991).
- Faculty instructional practices are shaped by a complex system; the entire system needs to be considered in change efforts (Colbeck, 2002; Kezar & Eckel, 1992; Porter & Roessner, 2006; Skoldberg, 1991).

- The department level is the real power unit in universities and the best place to focus change efforts focused on teaching (Colbeck, 2002; Massey, et al., 1994; Skoldberg, 1991).
- Institutions must support faculty development (Hannan, 2005; Major & Palmer, 2006).
- Institutions need to value teaching in addition to research (Hannan, 2005; Porter & Roessner, 2006).

Evidence and Success of change interventions

Nine of the 13 articles examined reported on change interventions. Three of these 9 articles present evidence of success or lack of success of change intervention to at least moderate level. Six of these 9 articles present little or no evidence to support their assertions regarding the change intervention they report. Two articles recommend change strategies but do not study or make claims about their outcomes, and two did not describe an intervention.

Among the articles that provided at least moderate evidence of success or lack of success of the intervention studied, Colbeck (2002) presents interview data from 170 faculty at six institutions in two states to support her claims that the state-level policies were not effective in changing instructional practices. Faculty either were not aware of the policies or, if aware, were resistant to comply. Among the articles that presented little evidence to support their conclusions, Johnson (2006) claims that his institution was successfully transformed. However, the only data to this effect seems to be that 100% of faculty were assessed as “technologically competent” (criteria for the assessment were not clear).

Category IV. Environments/Emergent—Focus on developing shared vision

This category is defined by its intersection of focus on environment/structures and emergent outcomes. The emphasis of this type of intervention is on developing a new collective vision for the department, institutional unit, or institution (and, on occasion, even supra-institutional entities) that will support new modes of instruction. The change agent uses instructor (and typically other) stakeholders to develop a shared vision and to design new environments that are consistent with this vision. The primary change agent roles for this category are to empower and catalyze individuals to come together to develop a shared vision.

Only six articles remained in the Developing Shared Vision category after analysis. Several articles that appeared upon initial review to address shared vision, creation of culture, and harnessing of collective understanding to foster change were found upon deeper scrutiny to address how culture serves as a barrier or a variable in policy implementation. Such articles were moved to the policy category. In addition, a few articles that mentioned culture in their titles or introductions presented individual level change interventions. These were moved to the Reflective Teachers and Curriculum and Pedagogy categories.

The following subcategories were identified within this category:

- 1) Institutional-Level Actions (3 articles): collective decisions by stakeholders at many levels of an institution.

2) Externally initiated department level collaboration (2 articles): external agents (such as disciplinary accreditation) or institution-based change agents drive departmental level change.

3) Internally initiated department level collaboration (1 article): a department engages in collective reflection on instructional practices.

Common change statements

The articles in this category express some common ideas about change in faculty instructional practices. Due to the small number of articles in this category, some ideas are presented with fewer than two citations.

- Institutional re-emphasis on undergraduate education requires faculty commitment and loyalty to their home institutions, so institutions must find ways to support this faculty commitment with “realistic incentives” (Brand, 1992, p. 26).
- “To transform a culture, the people affected by the change must be involved in creating the change” (Brigham, 1996, p. 28).
- Applying a “research group approach” with which scientists are familiar to curricular and pedagogical change issues yields more commitment and better results than individuals could achieve on their own. (Marbach-ad, et al., 2007)
- Successful change requires both faculty and administrative buy-in and support. One or the other alone will not yield results (Browne, 2005).
- Culture change around teaching must start at the department level (Cox, 1995, Marbach-ad, et al., 2007; Quinlan, 2000).

Success of the change interventions

Three of the six articles analyzed offered at least moderate level of evidence of success. Two articles presented little or no evidence of success. One article did not study the results of a specific intervention.

Among the articles that provided at least moderate evidence of success or lack of success of interventions, Browne (2005) presented case study data that supported her assertion that the bottom-up (pedagogical) process and the top-down (structural) process of two change initiatives led to problems with the level not used. Among the articles presenting little or no evidence of success, Brigham (1996) presented only anecdotal evidence about the success of different approaches to Large Scale Events.

C. Cross category comparison and discussion

Each subsection below relates to one of the five research questions: 1) What strategies do change agents use?; 2) How does the use of change strategies differ by discipline?; 3) What and how much evidence of success was evident?; 4) What ideas about the nature of instructional change were evident?; 5) What kind of grounding in or use of the change literature was evident? Discussion of the first two questions is based on the analysis of 130 of the 295 articles meeting our search criteria; the next three questions on the more detailed analysis of 43 of the articles.

Change strategies used

Based on an analysis of 130 of the 295 articles meeting our search criteria, we developed four categories of change strategies (see Table 3). The vast majority of the articles we reviewed fit into one of these four categories: Developing Curriculum & Pedagogy, Developing Reflective Teachers, Developing Policy, and Developing Shared Vision.

Table 4 shows that change strategies described in the articles were much more likely to focus on changing individual faculty (61%) than on changing environments or structures (19%). In terms of desired outcome, the articles were more evenly divided between working towards prescribed outcomes (44%) and emergent outcomes (36%). Although the number of articles published may not be a perfect proxy for the activities of change agents, we expect a high correlation between the two since we are dealing with academic communities who place a premium on publishing their work. Thus, we conclude that change agents more frequently work at the individual level, rather than at extra-individual levels that involve environments or structures. These change agents implicitly or explicitly assume that individual faculty are able to make meaningful changes in their instructional practices without changes in the environment in which they work. As discussed below, from this perspective, authors often write about external environments as barriers to change that must be overcome.

Table 4 also shows that the least populated category is Shared Vision, at the intersection of Environment and Emergent. This category includes only 6 (5%) of the 130 articles. The lack of articles in this category implies that either change agents do not see developing shared vision as a productive change strategy or that change agents are unsure of how to implement this type of change strategy. Although we suspect the latter, this review does not provide us with enough information to support such a claim.

Use of different change strategies by different disciplines

One of our assumptions at the beginning of this project was that the three different disciplines (SER, FDR, and HER) each operate more or less independently of one-another and that each has their own distinct perspectives and strategies about change. The literature review presented here supports these assumptions. Figure 1 shows that the disciplinary background of the author(s) is related to the category in which we placed the article. This trend is easiest to see for HER, which has a strong focus on changing environments and structures rather than a focus on directly changing individuals. In contrast, both SER and FDR primarily focus on changing individuals. As one might expect, SER authors tend to write about discipline-specific activities and are most frequently found in the Curriculum and Pedagogy category, particularly subcategory 1 (Disseminate Best Practices). In contrast, FDR authors tend to focus on more general aspects of instructional improvement and are most frequently found in the Reflective Teachers category and, to a lesser extent, in the Curriculum subcategory 2 (Modify Instructor Conceptions).

Evidence to Support the Effectiveness of Change Strategies

A major goal of the analysis was to determine the nature and strength of evidence offered by authors. This process is an inherently subjective, and much discussion went into defining what constitutes strong, moderate, weak, and little or no support – the scale by which we ranked articles.

Of the 43 articles analyzed, 12 did not present a specific change strategy about which one would expect to see evidence of success. Some of these articles offered research that examined issues important to change, such as teacher beliefs and departmental norms. Others offered opinions, experiences, and reviews of the literature. Of the 31 remaining articles, we judged 12 (39%) to have at least moderate evidence supporting their assertions of success or lack of success of a change strategy. Six articles (19%) were judged to offer weak support, and 13 (42%) offered little or no evidence in support of their claims of success or lack of success. No articles were judged to have strong evidence supporting the success of a change intervention. This may be due to the difficult nature of studying and documenting a complex process within complex environments.

Overall, the articles, across categories, that did present at least moderate support for the success (or failure) of the change strategy studied, or of the conclusions and recommendations offered, followed a pattern of systematic data collection – either quantitative or qualitative, or both – and coherently tied their conclusions and recommendations to the data they present. In addition, many informed their change strategies from the literature. Those articles that were weaker often had data collected in a similar manner to the stronger articles, but did not present the data effectively or in depth, and offered conclusions and recommendations that were not supported by the data presented. Those articles with little evidence were often personal accounts of change that relied on anecdote.

Common ideas about instructional change

Another major goal was to identify ideas about the nature and process of change either explicitly stated or implicit within the change strategy or the article's conclusions and recommendations. When looking within and across categories, several interesting patterns emerge.

Twenty-five separate change statements were identified across the four categories. When examined more closely, six distinct foci emerged that encompassed the separate statements: 1) institutional structures, 2) individual faculty, 3) diffusion of innovations, 4) departments as the locus of change, 5) collective decision-making, and 6) multi-level buy-in. We examine these:

Institutional structures included 9 change statements mentioned by 23 articles and were found in all four categories. These were often presented as structural barriers to change, particularly in the Curriculum and Pedagogy and Reflective Teachers categories. Statements about institutional structures dominated the Policy category. These were generally positively or proactively framed, and ranged from stating the need for institutions to support faculty development to noting the complex systems that need to be considered in change processes.

Individual faculty factors included 7 change statements mentioned by 17 articles across two categories: Curriculum and Pedagogy and Reflective Teachers. Statements were often in the form of barriers to change. The most commonly cited ideas were that faculty lack knowledge about student-centered teaching, faculty are skeptical of new approaches, and change takes substantial faculty effort. Within the Curriculum and Pedagogy category, all individual faculty-related statements noted barriers to change. Within the Reflective Teachers category, these statements were more neutral, noting that teaching is context dependent and requires individual faculty adaptation, and that the typical faculty development advisor/client approach is not ideal for faculty change.

Ideas about the diffusion of innovation and change were found in three statements mentioned by 5 articles in the Curriculum and Pedagogy and Reflective Teachers categories. The overall idea expressed is an expectation that changes initiated by one or a few members of an academic group (such as a department) would spread to others in that group once the changes are demonstrated to be successful. Some articles concluded that this does not commonly happen.

The department as the locus for change includes three change statements mentioned by 8 articles in three change categories (Reflective Teachers, Policy, and Shared Vision). The overall idea expressed by these statements is that the department is the power unit in universities, and the best (and sometimes only) place from which change can successfully start.

Collective decision-making is unique to the Shared Vision category, with two statements mentioned by 2 articles. The idea expressed was that those whom a change affects must be involved in creating that change, and that collective or collaborative processes used for other work can (and should) be brought to bear on instructional change.

A final focus – *Multi-level Buy-in* – was mentioned by only one article in one change category (Shared Vision), but was the sole statement examined that did not fit within the other five foci described above. The idea expressed in this statement is that successful change requires both faculty and administrative buy-in. One or the other will not suffice.

It is interesting to note that the most prevalent change statements within the Curriculum and Pedagogy and Reflective Teachers categories focus more on individual and structural barriers to change than on support processes. Statements within the Policy and Shared Vision categories do not typically address individuals. They do address structures, but less as barriers and more as factors to be considered and harnessed for change. Articles within these two categories also mention organizational cultures as important more frequently than do articles in the individually oriented categories.

Connections between instructional change literature and broader change literature

The final goal of the further analysis was to identify how the articles used, if at all, the broader change literature. We purposely left the definition of “change literature” very open and liberal, in order to capture the full range of literature and ideas being used by authors to either develop and justify the change strategies they describe in the articles, or to apply as a lens for studying change strategies. Therefore, our conception of “change literature” encompasses literature on ideas such as reflection, action research, diffusion of innovation, organizational culture, organizational policy, organizational theory, as well as other social science theories. We were also interested in how many articles drew from common literatures.

The most important finding is that less than half (20/43) of the articles cited literature that we could label “change literature” despite our broad definition. Those that did not fit within our assessment of using change literature typically not only failed to ground their selected change strategy in the change literature, but also failed to justify their choice of change strategy in any way.

Overall, there was little overlap across categories in the kind of literature used. The exceptions were ideas of reflective practice (sometimes with citations, sometimes not), and department and higher education cultures, which were cited with both Policy and Shared Vision articles.

IV. Concluding thoughts

Perhaps the most important finding from this analysis is that it appears to be possible to use two relatively simple criteria to usefully categorize articles about STEM instructional change into a small number of meaningful categories. There were very few relevant articles that could not be categorized based on the scheme developed here.

In addition, the categories and subcategories presented here support our assumption that the three disciplines (SER, FDR, and HER) operate independently and use largely different strategies for promoting change. This finding supports our expectation that interdisciplinary work involving researchers from SER, FDR, and HER will be productive since each group can bring different sets of knowledge. There is also no evidence that we have somehow missed an important disciplinary community. There were relatively few authors from outside SER, FDR, and HER communities (i.e., those identified as “other” in Figure 1) and these authors did not appear to share any relevant unifying characteristics.

Another important finding is the presence of common weaknesses across all four change categories and all three research communities. This suggests that studying and promoting STEM instructional change is difficult. Many of the articles did not present convincing evidence to support the conclusions drawn and many articles did not build arguments and change strategies from the research literature. One possible reason for this situation is that since the literature is distributed in a wide variety of locations (the 295 articles in our database represent 108 distinct journals) it is difficult for authors in this area to find out about previously published work. This finding suggests that there is substantial need for synthesis work such as the work represented by this project. It also suggests that there is substantial need for work and effort focused on producing high quality studies that build on previous work.

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Appendix A -- Coding sheet for preliminary analysis.

Category	Codes
Discipline (which disciplinary audience is being spoken to, as defined by the journal)	HER FDR SER --biology, chemistry, engineering, geosciences, math, physics, technology OTHER
Author affiliation	HER FDR SER --biology, chemistry, engineering, geosciences, math, physics, technology OTHER
Primary Stated Purpose of Article (If article is review or other, skip to Significant Findings/Claims)	Generative Theory Development (Development of new ideas, concepts, theories) Convergent Theory Development (Examination, revision and/or testing of ideas, concepts, theories) Descriptive – Mainly describes an activity or situation Review Other
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
Research Approach	
Design	Naturalistic Experimental/Quasi-experimental Non-Empirical (no data collected)
Methodology	Qualitative Quantitative Mixed-Methods (both qualitative and quantitative)
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
Findings	
Significant Findings/Claims	Studying Change Designing Change Both Neither
Studying Change – open	
Designing Change – open	
Quality (Claims Supported by Evidence)	Strongly supported Mixed in support Weakly supported
Short summary - open	
Keep/eliminate	Keep for further analysis Eliminate from further analysis
Comments	Open