

## Project Directors

**Charles Henderson**  
Western Michigan  
University

**Andrea L. Beach**  
Western Michigan  
University

**Noah Finkelstein**  
University of Colorado,  
Boulder

**R. Sam Larson**  
Kaiser-Permanente  
and Regis University

# Preliminary Categorization of Literature on Promoting Change in Undergraduate STEM

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## Overview

While decades of research have identified effective programs and practices for improving STEM education, national models for sustaining and institutionalizing these programs and practices in higher education remain to be synthesized into coherent frameworks. Scholars in at least three fields have engaged in research on pedagogical change in STEM topics with the same goal: to improve student learning. *Disciplinary-based STEM Education Researchers* (SER) are generally housed in STEM disciplines within colleges or Arts and Sciences or Engineering and have largely focused on change in curricula and pedagogical materials meant to help students learn disciplinary content. *Faculty Development Researchers* (FDR) tend to be connected with centers for teaching and learning or colleges of education, and have traditionally focused on providing faculty with pedagogical skills and on motivating and empowering them to focus on instructional improvement. *Higher Education Researchers* (HER) are generally housed in Colleges of Education, and often study and discuss how cultural norms, organizational structures, and state and national environments and policy influence the higher education practices. Efforts in all areas, despite significant funding and study, have met with only modest success. Although the fields share an overriding goal, the research generated by each rarely “crosses over” to inform the others.

The educational change strategy synthesis project proposes to critically review and integrate the research literatures and perspectives of the SER, FDR, and HER communities through a meta-synthesis process to identify the change strategies, concepts, and theories that have the most promise for future work. Ultimately, this project aims to support the development of an interdisciplinary research and practice agenda for STEM instructional improvement.

## Literature Review Methods

Goal of the literature review:

1) Identify and describe core approaches to promoting changes in instructional practices used in undergraduate STEM education and the implicit and explicit assumptions behind each of these approaches; 2) Identify evidence that supports each of the core approaches; 3) Identify strengths and weaknesses of each of the core approaches; 4) Identify promising areas for future effort.

This document is a preliminary response to goal #1. It describes four core approaches and the assumptions behind these approaches. It is expected that each of the four core approaches will be further sub-categorized in subsequent analyses.

#### Articles included in literature review:

Initial sources – journal articles published since 1995 that describe efforts by change agents to improve the instructional practices used in undergraduate STEM education. (Note: by “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.) A search of Web of Science and ERIC databases yielded approximately 250 relevant articles. It is expected that additional articles will be added based on searches of individual journals that are not indexed, reference lists in current articles, and recommendations from other researchers who work are familiar with the literature.

Secondary sources - Based on a cited reference analysis of the initial sources, secondary sources will be identified from frequently cited works. These secondary sources may be foundational works published prior to 1995, influential or novel conference proceedings or white papers, or works not directly related to instructional change.

#### Analysis Procedures

We undertook an initial examination of 75 randomly chosen articles from the set of 250 identified as relevant. We used an inductive analysis process that involved reading and initial coding to identify the research community of the authors, the focus of the change approach, and the degree of specificity of the outcome intended. From these initial coding approaches emerged two guiding questions that, when answered and combined, form four categories of change strategies. We then reviewed the 75 articles and placed them within the categories developed. The results are presented below.

### ***Definitions***

#### **Two key categorization criteria**

The four proposed categories of strategies are based on the answers to two questions: 1) What is the primary aspect of the system that the change approach seeks to directly impact (individuals or environments)?, and 2) To what extent is the intended outcome of the individual or environment known in advance (prescribed or emergent)?

Individuals vs. Environments

What is the primary aspect of the system that the change approach seeks to directly impact?

<b>Individuals</b>	<b>Environments</b>
Definition: The change intends to directly impact personal characteristics of single individuals, such as beliefs, knowledge, behaviors, etc.	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.
Implicit Assumption: Individuals' actions primarily influenced by their own volition	Implicit Assumption: Individuals' actions are primarily influenced by external environments

Prescribed vs. Emergent

To what extent is the intended outcome of the individual or environment known in advance?

<b>Prescribed</b>	<b>Emergent</b>
Definition: The desired final state of the individual or environment is known at the beginning of the change process.	Definition: The desired final state of the individual or environment is developed as part of the change process.
Implicit Assumption: Important knowledge exists in a few special people (e.g., experts) who should tell others what to do.	Implicit Assumption: Important knowledge exists in individuals throughout the system and may be context-dependent.

## Four Core Categories of Change Strategies

Based on the possible combinations of responses to the two categorization criteria, there are four core categories of change interventions. They are summarized in the table below and described in more detail in the text that follows.

	Intended Outcome: Emergent		
Aspect of System to Be changed: Individuals	Change Lever: TEACHERS  Change Process: Encourage/Support individuals to develop new teaching conceptions and/or practices.  e.g., reflective practice (FDR), curriculum development (SER)	Change lever: CULTURES  Change Process: Empower/Support stakeholders to develop new environmental features that support conceptions and/or behaviors that will likely lead to changes in instruction that the stakeholders value.  e.g., institutional transformation (HER), learning organizations (HER)	Aspect of System to Be changed: Environments
	Change lever: CURRICULUM  Change Process: Tell/Teach individuals about new teaching conceptions and/or practices and encourage use.  e.g., dissemination/training (SER, FDR), focused conceptual change (FDR)	Change lever: POLICY  Change Process: Develop new environmental features that Require/Encourage new conceptions and/or behaviors that will likely lead to changes in instruction.  e.g., policy change (HER), strategic planning (HER)	
	Intended Outcome: Prescribed		

### Individual/Prescribed

Change lever is Curriculum/pedagogy: The focus of this type of intervention is on communicating the change agent's vision of good teaching to instructors. The emphasis is on the curriculum materials, instructional strategy, and/or associated instructor knowledge/conceptions. The change agent has 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.

Primary literature bases: Learning Theory (e.g., behaviorism, constructivism), Training, Communications (e.g., diffusion of innovations, persuasion).

Primary change agent roles: Teach, Sell

Ideal Example: Someone external to an instructor's institution (e.g., a curriculum developer) tells him/her about a new and better way to teach relevant content in the instructor's discipline.

### Individual/Emergent

Change lever is Teachers: The focus of this type of intervention is on encouraging teachers 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) that they hope 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.

Literature base: Reflective practice (e.g., Argyris & Schon; Leve & Wenger)

Primary change agent role: Encourage

Ideal Example: A faculty developer within an instructor's institution invites him/her to join a faculty learning community that will meet every other week to discuss instructor-initiated action research projects.

### Environments/Prescribed

Change lever is on policy: The focus of this type of intervention is on developing appropriate environments (e.g., rules, reward systems, reporting requirements) to ensure that instructors engage in desired activities. The change agent has a particular vision towards which they wish to require instructors to work towards. Typically this means that an instructor must adopt a particular activity, strategy, conception, or outcome. While, in the interventions that focus on individuals, internal motivation is the primary mechanism to control instructor compliance with change agent wishes, here significant incentives or requirements are used.

Literature base: Management (earlier – 1970's and 80's, e.g., top-down factory-styles)

Primary change agent role: Command

Ideal Example: An administrator at an institution is concerned that instructors primarily use low-level test questions. The administrator decides to require that instructors document their use of higher-order questions on tests.

### Environments/Emergent

Change lever is Cultures: The focus of this type of intervention is on developing a new culture for the department, institutional unit, or institution (and, on occasion, even supra-institutional entities) that will support new modes of instruction. Stakeholders are involved to help shape this new culture and help determine what types of environments will be necessary to support the new culture. 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.

Literature base: Management (more recently – 1990's and 00's, e.g., shared-ownership team-based styles)

Primary change agent roles: Empower, Catalyze

Ideal Example: A department chair is concerned about student learning outcomes in the department and invites a consultant works with a department over a semester to identify current weaknesses in undergraduate teaching and identify a strategy to improve them.

## ***Appendix A: Examples of Articles representing each category***

### Individual/Prescribed

#### a. Clear Ones

Foertsch, J., et al. (1997) Persuading professors: A study of the dissemination of educational reform in research institutions. University of Wisconsin-Madison, LEAD Center.

Used 4 different methods to disseminate instructional reforms to faculty (unsolicited mailings, website posting followed by mailing, seminars followed by mailing, mini courses with materials). Interviews with 30 participating faculty used to draw conclusions.

Trigwell, K., et al. (1994) Qualitative Differences In Approaches To Teaching 1st Year University Science. *Higher Education* 27, 75-84.

Studied intentions of 24 university science faculty. Found that intentions were logically related to strategies. Conclude that rejection of suggested instructional strategies may occur if they do not fit with faculty intentions.

#### b. Difficult one

Candy, P., and Borthwick, J. (1994) The ally within: An innovatory approach to networking and staff development. *Innovative Higher Education* 18, 189-204.

Describe faculty development model at Queensland University (Australia). Academic staff development unit (ASDU) associates provide professional development activities in their units consistent with local needs. "Increasing numbers of staff are in day-to-day contact with an individual - that ASDU associate - who is advocating" the importance of quality in university teaching performance. No data presented. [Note: this one is categorized here because the ASDU associates are the ones who decide what professional development the other faculty need.]

### Individual/Emergent

#### a. Clear One

Krockover, G.H., Daniel P. Shepardson, David Eichinger, Mary Nakhleh, Paul E. Adams (2002) Reforming and Assessing Undergraduate Science Instruction Using Collaborative Action-Based Research Teams. *School Science and Mathematics* 102.

Three teams (scientist, science educator, teacher, preservice teacher, TA) worked on collaborative action-based research (CABR) to reform 3 individual courses. Authors conclude that this is a successful model for developing instructional changes that fit with the local setting. Also noted structural constraints to the use of CABR.

#### b. Difficult ones

Fink, L.D., et al. (2005) Becoming a professional engineering educator: A new role for a new era. *Journal of Engineering Education* 94, 185-194.

Nice summary of change literature related to engineering education. Basically argue that university culture needs to change in order to support faculty in SoTL activities. Two case studies are presented, but this really is an opinion piece. [Note: this is categorized here because the basic argument is that SoTL is an appropriate change intervention, but that there are barriers to the use of SoTL.]

Gaidi, K.E. (2003) Reforming Engineering Education: The CDIO Initiative. *Industry and Higher Education* 17, 431-434.

Describes CDIO initiative, which is a reformed model for engineering education developed by 4 institutions. They hope that by developing this initiative and providing information/materials/etc. to other institutions that CDIO will spread. No data and few specifics are included in the article. [Note: this is categorized here because the main emphasis of the article is on the change initiative that allowed change to occur at the four initial institutions.]

### Environment/Prescribed

#### a. Clear One

Gibbs, G., and Coffey, M. (2004) The Impact Of Training Of University Teachers on their Teaching Skills, their Approach to Teaching and the Approach to Learning of their Students. *Active Learning in Higher Education the Journal of the Institute for Learning and Teaching* 5, 87-100.

Study of effectiveness of university-based training programs (often compulsory and mainly for new faculty). 22 Universities in 8 countries. 104 teachers in treatment, 10 in control. Used closed-format instruments for teachers and their students. Found a positive impact in training group

#### b. Difficult one

Wright, W.A., Peter T. Knight and Natalie Pomerleau (1999) Portfolio People: Teaching and Learning Dossiers and Innovation in Higher Education *Innovative Higher Education* 24, 89-103.

Article supports institutional use of teaching portfolios to help faculty reflection and improve their teaching. Identifies likely difficulties with the institutionalization of teaching portfolios and argues that these need to be addressed by the institution in order for change to be successful. [Note: this is categorized here because there is a policy change that seeks to promote faculty use of teaching portfolios.]

### Environment/Emergent

#### a. Clear One

Brigham, S.E. (1996) Large scale events: New ways of working across the organization. *Change* 28, 28-39.

Review article that identifies 8 types of large-scale events that have been used in higher education. Contrasts traditional ways of thinking about change (top-down, planned) with systems thinking. An important assumption is that knowledge is distributed throughout the system.

#### b. Difficult one

Browne, E. (2005) Structural and Pedagogic Change in Further and Higher Education: A Case Study Approach. *Journal of Further and Higher Education* 29, 11.

Case studies of two universities introducing information learning technology. One bottom-up, focused on pedagogy. One top-down, focused on structures. Conclude that structural and pedagogical issues must be considered together and lecturers and administrators must work together for change to be successful. [Note: this is categorized here since the primary conclusion is that stakeholders from different institutional perspectives must work together for a change that impacts multiple institutional levels.]



## Appendix B: Distribution of Article Authors

Note: Pie charts represent relative distribution of departmental affiliations of article authors. N represents number of articles in each category (from initial set of 75 articles). Some articles were not categorized because they were discarded from the analysis for lack of relevancy or they were review articles that spanned multiple categories.

