ECR: Creating transformational STEM education: A metasynthesis mapping a decade of systemic change research

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Introduction

Significant research has been devoted to enhancing STEM-related pedagogical practices that produce better academic outcomes for undergraduate students from different educational and social backgrounds [1-4]. Despite the proliferation of researchers across various educational disciplines focused on STEM-related pedagogical practices, less effort has been devoted to systematic analyses of change-related practices and how these studies adopt specific theories of change and their strategies for dissemination. A previous NSF-funded project [5] addressed this gap by conducting a thorough interdisciplinary literature review of research devoted to changes in undergraduate STEM instructional practices, illuminating the various theories of change employed by different scholarly communities to improve undergraduate STEM education. The theoretical insights from this metasynthesis have been a widely cited resource for scholarly communities devoted to STEM-related instructional practices [6]; however, the proliferation of research in the decade plus since its publication requires a new analysis incorporating more recent research.

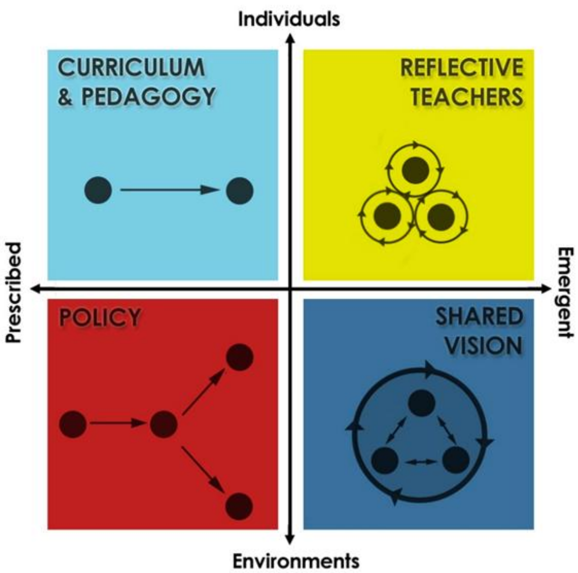
Purpose

This paper presents preliminary results of our NSF ECR project (Award #2201792) that conducts a comprehensive, multi-method metasynthesis of literature published between 2011 and 2023 on evidence-based strategies for improving undergraduate STEM instruction. Building on and updating our foundational review [5], we examine instructional change strategies reported in the literature following publication of the 2011 framework. Although the body of research on instructional change in higher education has expanded substantially and the 2011 framework has been widely cited, no systematic and comprehensive review of this literature has been conducted in the intervening years. This metasynthesis addresses that gap by investigating how the field has evolved, including the extent to which the four categories of change strategies from the prior review [5] have been adopted, adapted, or overlooked; whether new or hybrid change strategies have emerged; and how the theoretical grounding, methodological approaches, and empirical rigor of studies have changed over time.

Conceptual Framework

The conceptual framework of the current project is the four-square typology of change strategies based on our prior work [5]. In the prior work, we conducted a synthetic review of 191 conceptual and empirical journal articles focused on systemic change in STEM education in the

United States published between 1995 and 2008. Four broad categories of change strategies were developed to capture core differences within this body of literature: disseminating curriculum and pedagogy, developing reflective teachers, enacting policy, and developing shared vision [5].



These categories are characterized by two dimensions: the scale of impact/aspect to be changed (individuals or the educational environment) and the intended outcome (prescriptive or emergent change). Figure 1 displays the four-square typology of change strategies with brief descriptors for each of the quadrants. Recommendations for systemic and sustainable change efforts include working across multiple change strategies indicated in the four-square diagram, taking a holistic ecosystems approach, focusing on the department as a key unit of change, and maintaining change efforts for the long haul.

Figure 1. *Four-Square Typology of Change Strategies.*

Method

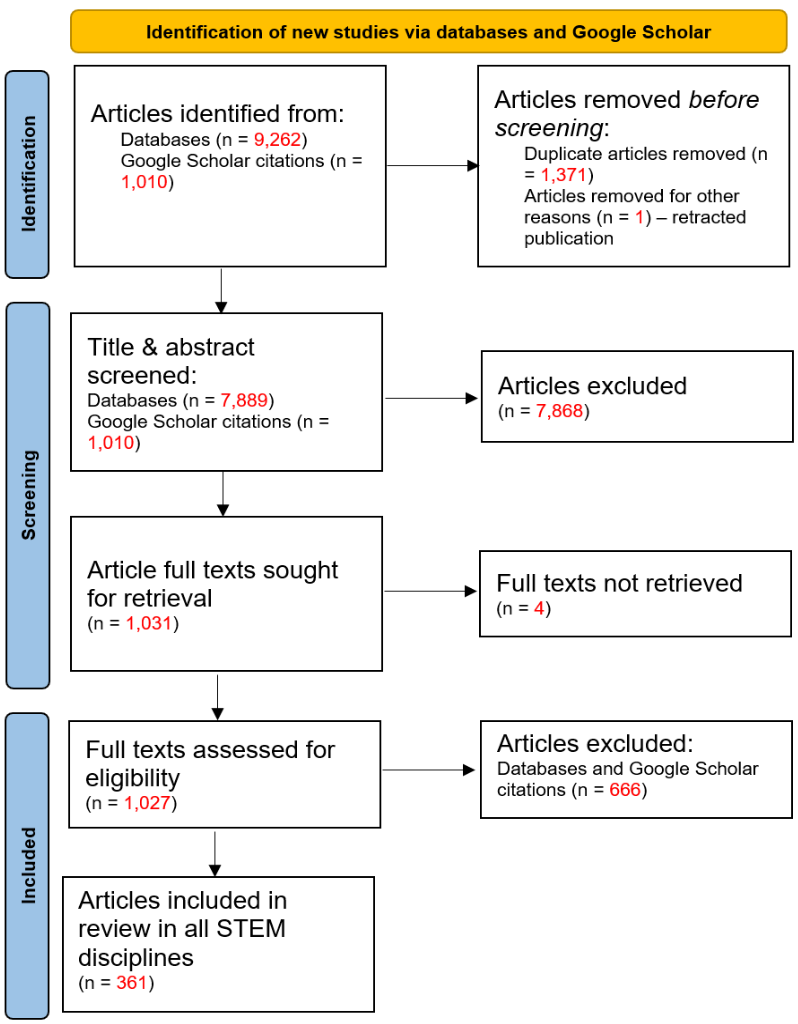
Searching

We identified search terms in multiple stages. We first used the search terms from the prior review [5] and then added STEM-specific terms to broaden the search to all NSF disciplines. We then conducted a manual hand search within STEM education and change journals to identify additional terms. Using the initial list of terms, we tested them in academic databases; initial searches yielded many medical education articles and studies from other countries. Therefore, we added exclusion terms using "NOT" (e.g., "nursing," "China"). Finally, we asked experts in systemic change, higher education, and systematic review for their feedback on the terms to finalize our search strategies and complete the searching. The library database we used for searching included *Academic Search Complete*, *Education Research Complete*, *EconLit*, and *Science & Technology Collection*, yielding 9,262 potentially relevant articles. We also searched Google Scholar for articles that cited [5], yielding 1,010 potentially relevant articles.

Inclusion criteria and screening

Articles for this study needed to adhere to the following inclusion criteria: 1) describe purposeful and strategic change in higher education in the United States; 2) describe an initiative or program designed for widespread change; and 3) provide empirical evidence about the change initiative or program. We screened in two phases, in alignment with PRISMA guidelines [7]: title and abstract screening before full-text screening. Prior to completing any screening, we trained all three screeners on the inclusion criteria and collaborated with the larger team to ensure all team members shared a common understanding of what should and should not be included before conducting independent screening. At both the title/abstract and full-text stages, we used EPPI Reviewer, a systematic review software that enables collaboration for screening, coding, and resolving disagreements [8]. After both screening stages, 361 articles were included in the analysis. Figure 2 displays the PRISMA flow diagram.

Figure 2. *The PRISMA flow diagram*.

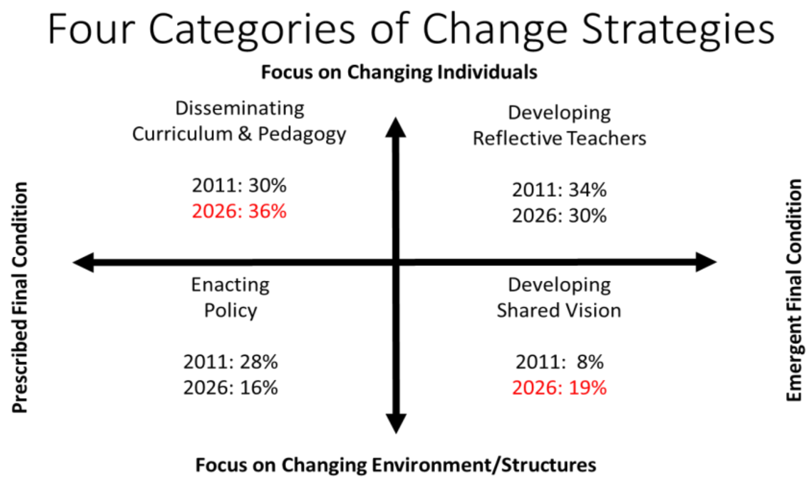


Analysis

We conducted qualitative coding of the articles' content, using key a priori codes from the previous study and developing new ones to capture important dynamics of change initiatives. A priori codes included specifics surrounding the systemic change project, such as how the initiative fit within the four-square typology of change, who the agents of change were, and the target of change. From screening and initial coding of the articles, the team added other codes that appeared relevant, such as whether the project was a response to the COVID-19 disruption to higher education, whether the change strategy focused on new technology, or whether the change specifically related to online instruction.

A team of four team members coded a set of articles collectively and held multiple training sessions to reach adequate reliability for coding all categories (e.g., change strategies, the change agent, the target of change, and the disciplinary patterns). Note that this paper focuses only on change in the distribution of articles in the main coding categories. Additional results from this study will be described in future publications.

Figure 3. *Comparison of 2011 and 2026 findings (Adapted from [4]).*



Results

Henderson et al. [4] original analysis included (n=191) articles and developed four conceptual categories to illuminate the change strategies employed within the research articles (See Figure 3): Disseminating Curriculum and Pedagogy (n=58, 30%), Developing Reflective Teachers (n=64, 34%), Enacting Policy (n=53, 28%), and Developing a Shared Vision (n=16, 8%).

The team used these conceptual categories to identify any shifts in the change strategy utilized within the 361 articles included in the update. They found an increase in Disseminating Curriculum and Pedagogy strategies (n=130, 36%) and Developing a Shared Vision (n=0, 19%). Examples of Disseminating Curriculum and Pedagogy include information on instructors' pedagogical beliefs [9] while Shared Vision relates to more structural change such as creation of an entrepreneurial pathways program that required buy-in from across the university and with an external business [10]. Fewer change agents employed Developing Reflective Teacher strategies (n=110, 30%) and Enacting Policy strategies (n=57, 16%). Developing Reflective Teachers work often sought to educate instructors on integrating more active learning in their courses while Enacting Policy worked to evaluate systemic reforms such as including writing into engineering curricula [11] or providing virtual labs for engineering technology programs [12]. From the updated literature from 2011-2023, thirty-four of the included articles (9%) employed more than one strategy, with three articles employing three different strategies and one article employing all four strategies. One example that used both Developing Reflective Teachers and Developing Shared Vision includes a reform that began with departmental Communities of Practice that created sustainability plans while also encouraging faculty to "teach like you do research" [13].

Limitations

The selection criteria for articles in both of these literature reviews were not identical. In the earlier review, we were somewhat more relaxed in the quality of empirical data required for inclusion in the study than in the current review. Thus, some of the articles included in the prior review would not have met the inclusion criteria for the current review. We do not think that this will meaningfully change the results presented here, and we are re-screening the articles from the earlier review to be able to make a fairer comparison. Results will be reported in a future paper.

Discussion

The results show the original four categories of change strategies still apply (with 10% or fewer) of the articles not neatly fitting into a categorization scheme. Additionally, we note the number of articles found in the 13 years between 2011-2023 (N=361) is nearly twice the number of relevant articles found in the 14 years between 1995-2008 (N=191), and quite possibly higher given the stricter review criteria in the current review. This suggests that there is greater acknowledgement now that change strategies are something that can be improved through scholarly study. This is a very positive finding since lack of research-based knowledge about how to create change is currently a limiting factor in improving undergraduate STEM education.

In terms of the types of change strategies used, we find that the distribution of strategies between the two levels of scale (individuals vs. environments) is quite similar in both reviews. Approximately ⅔ of articles are focused on individuals and approximately ⅓ of articles are focused on environments in each review. Within those categories, for articles focused on individuals, again, there is no difference in the distribution of articles in each of the reviews. The articles are roughly evenly split between a prescribed focus on individuals and an emergent focus on individuals. This suggests that change agents value both of these types of strategies equally and that this value has not changed in the last few decades.

While the percentage of articles focused on changing environments and structures did not change between the two reviews, the distribution of strategies between the two types of outcomes (emergent vs. prescribed) did change. In the more recent review the articles are roughly evenly split between these two types of outcomes, while in the earlier review, the articles were predominately focused on prescribed outcomes. One important result from the prior review was that emergent-environmental, or shared vision, change strategies were promising and underused. It appears that change agents are increasingly seeing the value of these strategies and are now using, or at least writing about, them with the same frequency as emergent-prescribed change strategies.

Conclusion

In an updated review of the literature on change strategies for the improvement of undergraduate STEM education, we find a very significant increase in the number of articles published about change strategies published from 2011-2023, nearly doubling that of a prior study from 1995-2008. This suggests that there is now a greater acknowledgement about the value of studying and improving change strategies. The more recent review also has a much larger percentage of articles that fall in the shared vision category, suggesting the community is attending to the potential of what had been a rare and yet promising change strategy.

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