Sustainable Change: A Model for Transforming Departmental Culture to Support STEM Education Innovation

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(Dated: December 10, 2014)

This paper describes a strategic effort to improve teaching and learning in STEM departments at the University of Colorado Boulder. In contrast to many other higher education STEM change efforts that focus primarily on disseminating practices, our two synergistic change strategies focus on explicit cultural change that integrates interventions across the entire university system, impacting faculty members, administrators, and, most importantly, whole departments. Our outside-in strategy works with both faculty and administrators to create changes that will combine to influence departmental culture, and our middle-out strategy works directly with departments to enact a large-scale cultural change process. Both of these strategies aim to align departmental cultures with six core cultural commitments that are emblematic of highly productive departments. We argue that this holistic approach to shifting culture is required to foster and sustain meaningful change. Additionally, our strategies are grounded in change theories that have emerged from decades of research into organizational change. We summarize these theories and illustrate their applicability to our change strategies in order to demonstrate their value in the context of STEM education transformation. We aim for our overall approach to provide a productive starting point for change efforts at other institutions.

PACS numbers: 01.40.Fk,01.30.Cc

I. INTRODUCTION

A growing body of evidence highlights the positive impact of active learning in STEM classrooms [1]. Active learning classrooms provide students with opportunities to construct their own understanding (e.g., through discussions and group work) rather than attempt to learn from teaching by telling through traditional lecture. Not only do students in active-learning courses outperform their peers, there is evidence of improvement in future course performance and persistence in STEM [2]. Despite this evidence, active learning practices are not widely implemented [3, 4].

To address this issue, there have been numerous calls to improve the adoption of effective, research-based pedagogies [5, 6]. The focus on adoption over development reflects the wealth of effective strategies that have already been created. Still, universities, departments, and individual faculty members routinely struggle to create pedagogical changes that are widely-adopted, successful, and sustainable.

Physics and the implementation of PER-based reforms demonstrate the challenges of scaling and sustaining educational transformations. The evidence suggests that almost all physics faculty members know about at least one research-based strategy, indicating that dissemination of knowledge is not a significant barrier to their use. However, of the physics faculty members who know about at least one strategy, about one-fifth do not try to use them; of those that do try, about one-third discontinue use after their initial attempt [3, 4]. This “adoption deficit” is often the result of environmental barriers that discourage the use of research-based strategies by physics faculty, including those with “non-traditional” conceptions of teaching and learning that are highly incompatible with the findings of education research [7]. One example of such a barrier is the significant mismatch between the measures of teaching effectiveness used by institutions and by instructors, neither of which coincide with the assessment practices suggested by the research literature [8]. In summary, effective teaching strategies have been developed, almost all physics faculty are aware of them, and there is evidence that these strategies are highly effective; despite this, they are still not widely adopted. Hence, there is a need to develop and implement models of institutional change that can support the widespread adoption of these strategies.

Typical approaches to educational reform assume that best practices can be developed, packaged, and disseminated to others. However, this strategy does little to recognize the deep-rooted institutional structures and cultural norms that complicate educational reform. Thus, success requires that change efforts attend to the particular cultures and structures of the institution. A wealth of literature on institutional change in business and government settings discusses change from this systemic perspective [9], but similar literature focused on higher education is less developed. Indeed, most of the higher education change literature does not explicitly discuss the theories of change that underlie the change efforts. The implicit and sometimes contradictory nature of these theories of change has led to change efforts that are not as
impactful as they could be, that cannot be easily cor-
rected when they fail to achieve desired outcomes, and
that cannot be easily translated to other contexts [10].
The lack of explicit theory demonstrates the need for
a broadening of perspective with respect to educational
transformation efforts in undergraduate physics in order
to bring about significant change.

This paper describes an effort towards sustained insti-
tutional change at the University of Colorado Boulder as
part of the Association of American Universities' STEM
Education Initiative, which has as its goal “to influence
the culture of STEM departments at AAU universities
so that faculty members are encouraged to use teach-
ing practices proven by research to be effective in engag-
ing students in STEM education and in helping students
learn” [11]. In the first half of the paper, we review what
is known about the six main categories of change the-
ories that permeate the institutional change literature
and use these categories to interpret some of the prac-
tices that characterize higher education change efforts.
Building on this summary, we discuss the change model
and strategies that we are using in our interventions in
several CU-Boulder STEM departments, explicitly mak-
ing connections to the six categories of change theories.
We aim for our model and approaches to serve as start-
ing points for similar efforts by physics departments and
faculty at other institutions.

II. INSTITUTIONAL CHANGE IN HIGHER
EDUCATION

Creating change in an institution as complicated as a
college or university is a challenging proposition, and yet
it is required for sustained, transformative innovations
in teaching and learning. Change efforts, whether im-
plemented locally or nationally, are informed by (often
implicit) underlying theories of change that connect the
details of the effort’s implementation with the desired
outcomes. If these theories are unsound or incomplete,
which is especially likely if they remain unstated and un-
analyzed, the change effort is less likely to succeed. While
there is not a strong tradition among STEM education
researchers of making theories of change explicit, organi-
zation change researchers have spent decades doing so.

In a recent book, How Colleges Change: Understand-
ing, Leading, and Enacting Change [10], Adrianna Kezar
describes six categories of change theories and develops
a framework for planning change initiatives in higher ed-
ucation. Here, we briefly summarize these categories to
give the reader a sense of their content and references
to learn more. We illustrate the theories with exam-
pies of STEM change efforts from Seymour [12]; Hen-
derson, Beach, and Finkelstein [13]; and Borrego and
Henderson [14]. By situating STEM change efforts in
the institutional change literature, we elucidate and con-
cretize the theories that emerge from this literature and
demonstrate their utility for implementing and studying

A. Six Categories of Change Theories

Kezar’s change framework encourages change agents
(anyone trying to create change, from administrators to
faculty to students) to move beyond a sole focus on the
content of the change towards a focus on the process
of change. In particular, she recommends that change
agents inform their approach to change with a critical
analysis of (1) the type of change, (2) the context for
change, and (3) the amount of agency or leadership they
themselves hold in the organization. Their approach is
then built out of strategies derived from six broad cate-
gories of change theories: scientific management, evolu-
tionary, political, social cognition, cultural, and institu-
tional. While one may look at these theories as compet-
ing against each other, a more productive view is that
they describe different aspects of a complex process that
may be more or less applicable depending on the details
of the change in question. Indeed, change agents should
consider all six categories when planning and executing
change.

In [12], Seymour presents over a dozen statements of
the logic that underlies STEM change efforts. She de-
"erives these primarily from an ethnographic study of pa-
pers, presentations, discussions, and participant feedback
from the third annual forum of the National Institute for
Science Education. This forum brought together 300 in-
dividuals from all levels of the education system, many of
whom were actively engaged in improving STEM educa-
tion. Because of the wide variety of institution types and
opinions towards change represented in this forum, Sey-
mours work provides a good representation of the logic
underlying real STEM education change efforts. We se-
lect a subset of those logic statements and analyze them
in the context of Kezar’s six categories of change theories.

In [14], Henderson et al. developed a typology of four
categories of change strategies that emerged from a 191-
article review of STEM educational transformation ef-
forts. The typology is organized across two dimensions:
the primary target of the change effort ((A) individuals vs. (B) environments) and whether the outcome was
known in advance ((1) prescribed vs. (2) emergent). This
led to four categories of change efforts (with their ob-
served prevalence noted in parenthesis): (A1) disseminat-
ing curriculum and pedagogy (30.4%), (A2) developing
reflective teachers (33.5%), (B1) enacting policy (27.7%),
and (B2) developing shared vision (8.4%). Although ef-
forts could be classified under multiple categories, 85.3%
of the articles reviewed fit cleanly into a single category.
In a follow-up work [14], Borrego and Henderson discuss
the logic that underlies eight specific types of change ef-
forts, with two from each of the above categories. These
are: diffusion and implementation (A1), scholarly teaching and faculty learning communities (A2), quality assurance and organizational development (B1), and learning organizations and complexity leadership (B2). As with Seymour’s logic statements, we analyze the logic that underlies these eight efforts in the context of Kezar’s six categories of change theories. For simplicity, we restrict ourselves to placing each of these change logics in only one of Kezar’s categories. This does not imply that, for example, faculty learning communities could not in principle draw from multiple categories. Instead, the category in which we placed a particular logic is the one from which it dominantly draws.

1. Scientific Management Theories

Scientific management theories take a rational, linear, and systematic approach to change. They assume that change efforts are initiated by organizational leaders and managers who guide the change process and that the rest of the organization will respond to this guidance in a purposeful, adaptive manner. Change strategies associated with this theory are assumed to transcend context: as long as careful planning precedes the implementation of change, all organizations should respond in the same way. Two well-known models within scientific management are organizational development, which emphasizes diagnosing problems and generating solutions on an ongoing basis, and reengineering, which emphasizes modifying organizational structure to create change. Leaders are responsible for aligning goals, setting expectations, modeling behavior, managing communication, and issuing rewards. Their toolkit includes strategic planning, providing incentives, implementing professional development, creating a vision, and providing feedback and evaluation. Two examples of change logics that draw from scientific management theories are:

“System change within institutions requires unequivocal, high-level commitment to promote and reward classroom effectiveness and educational scholarship” [12, p. 93],

and

“The fastest and most enduring way to promote a renewed emphasis on teaching in the service of learning in higher education is to restructure the faculty rewards system” [12, p. 97].

The first example explicitly describes change as originating with commitments at the top of the university hierarchy, and both of them focus on rewards structures (e.g., tenure and promotion, allocation of time and resources, opportunities for professional development) as a means of encouraging change to happen. While shifting rewards seems to be an important part of effecting sustained change in higher education, change driven entirely from the top is generally not effective [30]. One reason for this is the relatively diffuse nature of organizational structure in a university as compared with, for example, a typical corporation. Top down change efforts are also likely to be ineffective if they ignore aspects of the organization—institutional culture, individual beliefs, external pressures—that form the focus of other change theories.

Two STEM education change efforts identified in have underlying logics that use aspects of scientific management theories: implementation and organizational development. Implementation efforts involve structured activities that are designed to train instructors in the correct use of new educational innovations; their underlying logic is:

“STEM undergraduate instruction will be improved by developing research based instructional “best practices” and training instructors to use them. Instructors must use these practices with fidelity to the established standard” [14, p. 230].

Under this logic, the instructors are not the primary judge of the value or effectiveness of the “best practices” they are implementing. Instead, it is the job of educational experts to design the practices, the intervention by which the instructors will adopt the practices, and the metrics by which this adoption will be judged.

Similarly, organizational development strategies involve the planned change of some aspect of an organization’s vision or practices, generally driven by top administrators. The underlying logic is:

“STEM undergraduate instruction will be improved by administrators with strong vision who can develop structures and motivate faculty to adopt improved instructional practices” [14, p. 237].

Here we see a heavy focus on change as being driven by administrators (as opposed to collective action) and on the use of incentives to drive faculty behavior. Both implementation and organizational development are high-structure, top-down efforts, that exemplify scientific management theories.

Scientific management theories provide a vast array of practical strategies to change agents. A particularly important one in higher education is the use of incentives to influence behavior. However, these theories assume a top-down approach to change, completely rational actors, and organizational structures for which context is unimportant. Any or all of these assumptions could fail to hold in a particular change effort (e.g., universities have historically had relatively weak hierarchies). To use scientific management tools effectively, it is necessary to draw on complementary theories of change.
Evolutionary theories [32] emerged as a counterpoint to scientific management theories. Their core assumption is that change in an organization is caused by and depends on external factors which are usually economic (and much less so, political or social). Human agency is deemphasized [33]: the role of leaders is to manage unplanned yet unavoidable changes. Strategies at their disposal include proactive monitoring of and rapid responses to external factors [34], creating nimble infrastructure, and not allowing any part of the organization to weaken (since one never knows when an external factor will increase the importance of a particular part). Evolutionary theories also emphasize that organizations are complex systems with interdependent parts, and thus changes must necessarily impact all parts of the organization.

The logic that

“Attempts to alter single elements in a complex social system will not be effective: each element must be aligned with the others for system changes to prevail” [12, p. 96],

draws from evolutionary theories in that it acknowledges the interdependent, complex nature of universities. Additionally, Seymour discusses that alignment at the university level has to be explicitly addressed in an educational system that is not centrally planned because coherence is not built in (e.g., at the level of course design, there is no mechanism for assuring that course goals, assessments, and pedagogical techniques are aligned). If there is no externally-imposed coherence, a university will evolve towards a lack of coherence, especially if there are other factors to encourage that shift (e.g., financial pressures or the rise of online education).

Complexity leadership efforts derive from evolutionary theories in that they explicitly acknowledge the complex, interrelated nature of organizations and the difficulty in controlling such complex systems. Their underlying logic is that

“STEM undergraduate instruction is governed by a complex system. Innovation will occur through the collective action of self-organizing groups within the system. This collective action can be stimulated, but not controlled” [14, p. 241].

To stimulate change, complexity leadership recommends that change agents disrupt existing patterns, encourage novelty, and act as sense makers; the specific outcome of the resulting change is largely out of the control of the change agent.

Systemic thinking and the acknowledgement of the importance of external factors are strengths of evolutionary theories that are highly relevant to higher education; we will address the issue of external factors in more detail when we discuss institutional theories below. However, evolutionary theories are weakened by their sometimes unfounded assumption that individuals cannot do much to impact the change process.

Social cognition theories [32, 35–41] focus on the ways in which the thought processes of individuals can impact change initiatives [32, 41–44]. These theories grew out of investigations of resistance to change that found that resistance was often not the result of individuals disagreeing with the change in itself but rather with them not understanding the change process or its implications for their work. In this situation, the role of the change agent is to use strategies to help members of their organization to change their thinking, a task which is complicated by the fact that different people interpret the same environment very differently from each other [45]. Hence, change agents need to be able to see the institution through a variety of lenses to help others adopt unfamiliar perspectives.

Many efforts built on social cognition theories involve helping individuals make explicit the unconscious aspects of their worldview (referred to as “mental maps”) and confront prior beliefs with new information (i.e., using cognitive dissonance to encourage learning [38]). Indeed, social cognition theories leave open the possibility of change occurring spontaneously as members of an organization notice a dissonance naturally and then move to act on it. Tools available to change agents in social cognition theories focus on organizational learning (creating data teams and enhancing the infrastructure for collecting and interpreting institutional data) and sensemaking (encouraging interaction to help “synchronize” mental maps and providing professional development aimed at reexamining assumptions).

Social cognition theories are associated with the concepts of “single-loop learning” (or “first order” change) and “double-loop learning” (or “second order” change) [36, 37, 40]. The former is learning/change that improves what the organization already does while retaining existing organizational norms, goals, and structures. The latter is learning/change that challenges existing organizational structures in order to arrive at innovative solutions to problems that arise due to inconsistencies between organizational beliefs, actions, and consequences. Second order change is much more difficult to enact than first order change because the thought processes that lead to second order change can be threatening or embarrassing to individuals or to the organization and are thus ignored or made taboo. Hence, changes that arise “naturally” are generally first order.

Both

“It is necessary to provide clear and convincing evidence that all forms of teaching (whether innovative or traditional) are effective in promoting student learning. It is not
enough to claim that learning occurs; it must be demonstrated" [12 p. 100],

and

“Good ideas, supported by convincing evidence of efficacy, will spread “naturally”. On learning about the success of particular initiatives, others will become convinced enough to try them” [12 p. 92],

are logic statements that are derived from social cognition theories because they assume that change requires or is the result of individual learning. The first of these makes the claim that evidence of student learning is necessary for a particular teaching strategy to be adopted. While this may be true, such evidence is certainly not sufficient in many cases [17]. The second theory assumes that new data on teaching efficacy will spontaneously lead to different teaching practices. Social cognition theories allow for learning and change to happen “naturally” in the context of first order changes. However, the changes required to implement new teaching practices are frequently second order because they challenge existing norms and structures, and therefore will not occur unaided. This observation helps to explain Seymour’s comment that there is a lack of evidence of the effectiveness of efforts built on this logic statement [12 p. 92].

Efforts from [14] that are based on social cognition theories include diffusion, scholarly teaching, faculty learning communities, and learning organizations. These efforts focus on individual or group learning as sources of change, as do all efforts that derive from social cognition theories. However, only the learning organization approach focuses on explicitly uncovering and confronting unproductive mental maps, especially those that could be threatening or embarrassing; this makes it suitable for generating second order changes. The other approaches, especially diffusion and scholarly teaching, do not directly confront these maps, making them less likely to be useful for generating the kinds of second order changes needed to transform instruction in higher education.

Diffusion efforts rely on the underlying efficacy of an educational innovation to convince instructors to adopt it. Knowledge of efficacy can spread formally (e.g., via workshops) or informally (e.g., via word of mouth). Hence, this strategy is highly aligned with the second logic statement from Seymour mentioned above about “natural” spread of innovation. The underlying logic of this strategy is

“STEM undergraduate instruction will be changed when more individual faculty members treat their teaching as a scholarly activity” [14 p. 232].

A similar strategy is the creation of faculty learning communities (FLCs) [48], which seek to support scholarly approaches to teaching in a community setting. FLCs are groups of faculty, often cross-disciplinary, who engage in a collaborative process over a period of time (often an academic year) with the goal of each FLC member trying out and assessing a new teaching approach in his or her course. These communities can be quite effective in encouraging a scholarly approach to teaching, and their underlying logic is similar to the above:

“STEM undergraduate instruction will be changed by groups of instructors who support and sustain each others interest, learning, and reflection on their teaching” [14 p. 233].

Finally, learning organization strategies also focus on generating knowledge, but at a collective rather than individual level. In a learning organization, all parts of an organization (not just the top management or a group of experts) are continually developing and evaluating new ideas that lead to changes in the operation of the organization. This knowledge generation is tied to individuals making their mental maps explicit and public in order to effect second order change. The underlying logic of learning organization efforts is that

“Innovation in higher education STEM instruction will occur through informal communities of practice within formal organizations in which individuals develop new organizational knowledge through sharing implicit knowledge about their teaching. Leaders cultivate conditions for both formal and informal communities to form and thrive” [14 p. 240].

Social cognition theories have the benefit that they account for the complicated nature of human beings in the change process and the fact that the beliefs of individuals are critical to how change processes play out in practice. They also make the critical distinction between first and second order changes; while both types of change require learning according to social cognition theories, second order changes additionally require individuals to confront and change unproductive mental maps. However, social cognition theories are incomplete in that they focus on
learning via rational and traditional forms of evidence, without sufficient attention to learning through social and emotional (“irrational”) means.

4. Cultural Theories

Cultural theories [29, 32, 49, 50] assume that organizational change occurs as a result of cultural change, that is, a change in the values, beliefs, myths, and rituals of the organization. These changes are generally believed to be slow, unpredictable, and ongoing processes that occur “below the surface.” As such, they can occur without direct guidance: indeed, the implicit nature of culture means that change agents often don’t think to try to guide it. When change agents do try to guide changes in culture, the unpredictability of the changes means that the change process will be marked by emergent outcomes and need for constant adjustment. The main contribution of cultural theories to the change literature is an emphasis on context, values, beliefs, irrationality, fluidity, and complexity [51, 52].

Cultural theories share some features with social cognition theories; for example, they assume that different individuals in an organization hold differing views as to the nature of the organization’s culture. They also assume that change can be beneficial or harmful and can result in unintended consequences [53]. Because culture is such a deeply-rooted part of human experience, cultural change theories are particularly relevant to second-order change processes.

The underlying logic that

“Finding the means to leverage relevant shifts in departmental values and practices is the critical factor in determining whether the efforts of faculty—as individuals and groups—and of their institutions, will be able to improve the quality of [STEM] education, or achieve the wider goal of science-for-all” [12, p. 96],

derives from cultural theory: it focuses on change as being driven by shifts in values (although it ignores other aspects of what constitutes culture, like symbols and rituals). This statement puts particular emphasis on departmental culture, because “the department is the rock against which the teaching innovations of individuals or small groups of faculty are most apt to founder” [12, p. 96]. In other words, faculty are most impacted by the cultures of their departments (as opposed to other parts of the university, or the institution as a whole), which can include emphasizing the importance of research over teaching or the importance of the discipline over the institution.

One important distinction that will be relevant for our later discussion of change efforts at CU is between culture as a tool to effect change and culture as the object of change. Change strategies built on cultural theories of change use culture as a tool to effect change, although the target of the change could in principle be anything. On the other hand, the goal of our change efforts at CU is to alter the culture of STEM departments with respect to teaching and learning—culture being the target of the change effort—and we use a variety of theories of change (including cultural theories) to effect that change.

The implicit nature of culture leaves change agents with relatively few tools at their disposal to effect change. To be effective, change agents must take the time to understand the values that underlie the organization and align their messages about change with these values (or related aspirational values). They can also try to shift values by altering mission statements or using existing symbols or rituals in new ways.

5. Political Theories

Political theories [15, 32, 54] focus on conflicts between individuals or groups as the source of change. Philosophically, these theories assume that ideas (norms, values, beliefs) and their opposites are always present in an organization, and it is when these are brought into conflict (often due to resource constraints) that rapid, second-order, radical change occurs [32, 55]. These rapid changes punctuate long periods of slow, evolutionary change during which most members of the organization are disengaged from the potential conflict [56, 57]. Political theories allow for changes that can be quite erratic, irrational, and potentially regressive. While individuals are seen as important to catalyzing change, these theories place importance on collective action. Thus, the tools at the disposal of change agents include agenda setting, coalition building, mapping power structures, and negotiating [54]. While political changes could only benefit certain groups, empowerment approaches to political change encourage change agents to arrive at moral changes that mutually benefit everyone involved [58, 59].

The logic statement from [12] that aligns most closely to political theories is

“Change can be built from small local beginnings, first by provoking and maintaining conversations that lead to local collaboration; then by making connections with collaborators on the same or other campuses” [12, p. 96],

in that it suggests that local change agents can use agenda setting and coalition building to form the seeds for change. However, it does not explicitly address the existence of opposing camps that may come into conflict with this coalition. If the change agent fails to deal with these opposing camps effectively, then the change effort will be in jeopardy.

Political theories are very good at providing individuals positioned at all levels of an organization with ways to effect change. In the context of a university, coalition building and mapping power structures are particularly
important, especially for change agents outside of the traditional administrative power structure. One downside of political theories is that they tend to ignore important ideas from social cognition theories (e.g., that resistance could be due to misunderstanding rather than competing interests). None of the efforts discussed in [14] use political theories as a core aspect of their underlying logic.

6. Institutional Theories

Institutional theories [60–63] blend ideas from a variety of other change theories, but they are uniquely characterized by the attention they pay to the relationship between a target institution (a college or university, in the context of this work) with the network of other institutions that exert influence over it (e.g., other universities, professional societies, business groups, accreditation agencies, funding sources, and the legal system). These theories emphasize the significant pressure that can be exerted by this external network on an institution as it tries to maintain legitimacy while acknowledging that institutions can have significant “inertia”, especially those with long-standing missions and identities [61].

Isomorphism, the tendency of similar institutions to converge in their missions over time, is a central concept in institutional theories [64]. The emergence of “academic capitalism” in higher education [62, 63] (marked by the centralization of campus authority and the rise of market-based decision making and focus on revenue generation by campus administrations) is often viewed as a result of institutional forces, like the Bayh-Dole Act (which allows universities to pursue patents on innovations created with federal funds), investment of businesses in campus-based research parks, and corporate leaders on boards of trustees. Like evolutionary theories, institutional theories provide little guidance to the change agent apart from the advice to understand and leverage the impact of external institutions over which they have little control.

The underlying logic that “The time for development, implementation, and testing that agency grants provide, plus the prestige of such awards, will increase the chances that innovation will take root in the host institutions beyond the end of funding” [12, p. 100],

takes an institutional perspective on change by coupling the potential sustainability of an educational innovation with the support provided by funding agencies through the awarding of grants. While grants do carry institutional prestige, this theory ignores the host of other external institutional factors that may provide pressures that work against the sustainability of an education innovation. Also, universities don’t often support the research of their faculty when funding runs dry despite the investment of time and effort that has been made, so equivalent time and effort allowed by educational grants are no guarantee that innovations will be sustained.

An effort that is aligned with institutional theories is that of quality assurance. In the context of higher education, this refers to the process by which institutions conduct an external review (setting goals, conducting a self-study, hosting an external visit, and responding to the external review report), which is typically driven by the need to satisfy accreditation agencies. Hence, the pressure to conduct this type of quality control comes from an institution outside of the university. One can imagine a future in which other institutions require similar forms of quality control (e.g., the federal government requiring the universities meet certain standards in order to receive federal student aid money). Whatever the source of the external pressure, the logic of quality assurance is

“STEM undergraduate instruction will be changed by requiring institutions (colleges, schools, departments, and degree programs) to collect evidence demonstrating their success in undergraduate instruction. What gets measured is what gets improved [14, p. 235].

Hence, it is in a university’s best interests to have as much say as possible in the process by which the external institution decides what is to be measured.

7. Consequences for Effective Change Strategies

To summarize, we see that the logics that underlie typical STEM education change initiatives align well with change theories from the organizational change literature as described by Kezar. This alignment suggests that the lessons provided by that body of literature are applicable to change efforts targeting physics education even though that connection is not often acknowledged. One of Kezar’s main messages is that change agents must consider the implication of all six categories of change theories when planning their change strategies in order to be effective, and this is especially true in a complex system like higher education that requires second order change. However, efforts described in [14] are based on social cognition theories disproportionately often compared with the other five categories of change theories (4 out of 8 align with social cognition, while 2 out of 8 align with scientific management and 1 out of 8 align with each of evolutionary and institutional). None of the efforts described in [14] explicitly use cultural or political theories. This suggests that STEM change agents would do well to familiarize themselves with change theories beyond their current repertoire and use them when planning their change efforts. Moreover, it is not sufficient to think of these categories in isolation, as though one should be choosing the right (single) tool for the job. Instead, they must be applied in a holistic, interdependent way, so that each can provide its unique strengths.
Seymour and Henderson et al. provide evidence to support Kezar’s message. Seymour observed that few, if any, of the underlying logic statements she identified lead to successful change when applied on their own; in particular, she noted that “bottom-up” and “top-down” approaches seem to be ineffective in isolation [12]. Similarly, Henderson et al. found in their review that the dissemination of “best practice” curricula (category A1) and top-down policy making (category B1) are ineffective as isolated efforts [13]. These observations are simply special cases of the idea that second order change in complex systems requires the use of multiple categories of change theories to be successful. Thus, Kezar’s framework helps to explain situations in which STEM change efforts fail while providing guidance on how to succeed.

III. TWO STRATEGIES FOR CHANGE AT CU

Many STEM education change initiatives directly focus on changing the practices that individual faculty members use in their classrooms. We take a different approach: the goal of our change effort is to shift the culture of STEM departments on CU’s campus in order to achieve the widespread use of sustainable, student-centered, evidence-based, active learning pedagogy in STEM classes. Our focus on cultural change at the department level recognizes that the university is a complex system and that the changes required to broadly shift teaching practices are second order changes that involve more than just individual faculty members.

To achieve this goal, we have developed two complementary change strategies that are built on a model of the University of Colorado as a collection of interrelated parts. We aim to effect change that results in a better alignment between departmental culture and a set of six core commitments that form the basis of an exemplary, productive culture. We will discuss our model, core commitments, strategies, and progress to date in the rest of the paper, with a special focus on connecting these to the categories of change theories introduced in the first half of the paper. We report on our progress with three departments: the Transfiguration Department, the Potions Department, and the Herbology Department (actual names redacted for confidentiality).

A. The Model

Fig. 1 is a visual depiction of our model for a university. Our model breaks the university down into three “levels”: faculty, department, and administration. Each of these levels can influence and is influenced by the adjacent levels; this influence is represented by the “internal” arrows in the diagram. One important feature of our model is that there are no arrows directly connecting the administration and the faculty. This is the case because the department acts as mediator between individual faculty members and the administration. For example, the department influences the ways in which administrative visions and priorities become translated into the day-to-day functioning of the university as enacted by the faculty, especially with respect to its educational mission. Similarly, departmental norms and rules shape the ways in which faculty members interpret their roles, responsibilities, and levels of influence in the governance of the university. Because of this mediating function, we take the department to be the key locus for change in the university [11, 13]; it is the target of our transformation efforts.

The “external” arrows in our model represent the influence exerted on different levels of the institution by our project team, including already-existing external pressures that can be leveraged by our project team. Our focus on the department does not mean that we ignore other parts of the institution; instead, there are components of our change strategies targeted at all three levels. In the outside-in strategy, we target the faculty and administration levels directly in such a way as to impact the departments. In the middle-out strategy, we work directly with departments, indirectly influencing the faculty and administration. We view these strategies as synergistic in that they can both operate simultaneously to impact the same department. We elaborate the details of these strategies below.

As with all models, ours necessarily makes simplifications. First, the boundaries between faculty, department, and administration are not as clear-cut in reality as in

FIG. 1. (Color online) A model of a university as consisting of three “levels”: faculty, department, and administration. The “internal” arrows represent the influence that one layer can have on the others, while the “external” arrows represent the influence of external change agents. Two change strategies are illustrated: the outside-in strategy (blue) and the middle-out strategy (orange).
the model. For example, department chairs have an administrative role, so they are part of both levels at once. Deans are closer to departments than are provosts and are often drawn from the university’s faculty rather than brought in from outside the institution. A group of faculty members working as a team can be thought of as falling between the faculty and department levels. Nevertheless, the sharp distinctions between these groups in our model helps us to articulate the influence that each exerts on the other and to develop interventions that target each level in an appropriate way.

Additionally, our model does not include undergraduate students, graduate students, postdocs, or staff, all of whom are important players in the operation of a university. Further refinement of this model could include any or all of these groups as levels, with appropriate change strategies targeting them.

B. Core Commitments of Target Departmental Cultures

Our efforts aim to shift university STEM instructors towards the increased use of student-centered, evidence-based, active learning practices by influencing the culture of STEM departments. Schein defines organizational culture as “a pattern of shared basic assumptions learned by a group as it solved its problems of external adaptation and internal integration, which has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems” [65, p. 18]. Thus, culture arises as a group confronts and solves problems; whatever assumptions seem to have consistently worked well for them become part of the group’s culture and inform future problem-solving and decision-making. A group’s culture cannot be directly observed; instead, it must be inferred from outward signs, such as stories (explanations about why events happen), rituals (regularly repeated sets of actions), tools (things used to accomplish a task), and practices (actions performed to accomplish a task).

Because of the relationship between culture and practices, cultural change can be a driver of changes in practices. As we saw in our review of institutional change efforts, the majority of these focus on altering practices either through changing what individuals think (i.e., social cognition) or through authority (i.e., scientific management) rather than through cultural change. Our efforts take a complementary approach that focuses directly on influencing culture to effect the changes in practices that we would like to see.

If one intends to shift the culture of a group, it is important to have a clear vision of the features desired in the target culture. This is especially important for strategies such as ours that require coordination between interventions that target the university at multiple levels; for example, we need to know what our desired culture looks like in order to align our efforts at the faculty and administration levels in the outside-in strategy. Our target departmental culture is characterized by six core commitments. We believe that a department that internalizes these commitments will create an improved educational environment for STEM undergraduates, including substantial use of active learning pedagogies. We expect that departments will adapt and contextualize these commitments as they incorporate them as a subset of their overall goals. The commitments are:

C1 Students are viewed as partners in the education process: Students play an active role as partners in the education process, not simply as recipients of education. Students current understandings are seen as a resource to be built upon, and students engage in higher-order thinking as part of their course experiences. Students have opportunities to exercise agency and voice in their education by playing an active role in setting outcomes and goals for their academic program.

C2 Educational experiences are designed around clear learning outcomes: Outcome thinking focuses on the end states to be achieved. Thus, learning outcomes specify the qualities, capacities, and understanding desired for students at the end of any given learning experience (from an individual assignment, to a course, to the major as a whole). The determination of appropriate outcomes is guided by the long-term developmental needs of students as people, scholars, and professionals in their field of study. Choices related to pedagogical practices are guided by these learning outcomes rather than a priori preferences.

C3 Educational decisions are evidence-based: The department and its faculty use evidence as the basis for making educational decisions, with a clear process for doing so. The department collects meaningful data about student learning outcomes to assess whether or not students are actually meeting these outcomes. The department regularly consults the educational research literature in its decision-making.

C4 Active collaboration and positive communication exist within the department and with external stakeholders: Faculty, students, and staff engage in an ongoing dialogue about education that reflects their shared, collective responsibility towards meaningfully supporting student learning. Mechanisms exist for identifying, understanding, and resolving conflicts among department members and with constituent groups. The department has informal gathering spaces that encourage discussion, collaboration, and community building among faculty. The department exhibits evidence-based best practices in decision-making processes.

C5 The department is a “learning organization” that is focused on continuous improvement:
The department uses systems thinking, seeing department functions (e.g., teaching, research, and service) as integrated, not separate. Improvement takes place across the departmental system, with explicit attention to the relationships among goals, functions, and actions. The department develops the capacities of individual members through training and team learning, and aligns rewards and incentives with desired outcomes (including learning outcomes). Department members reflect on their actions, are willing to revise their assumptions, and are open to attending to events in new ways. These practices lead to continued learning, and as a whole, the department becomes better at learning how to learn.

C6 The department values inclusiveness, diversity, and difference: The department makes efforts to recruit, retain, and support individuals from underrepresented groups, broadly defined. The department is mindful that its choices will affect different populations differently and therefore acts in ways that are supportive of all communities within the department and served by the department. The department prepares students to work in a diverse society and works to promote a culture of inclusiveness in society.

C. Readiness for Change

Just as we must assess and engage with students’ prior understanding to help students develop during instruction, so too must we understand the departments and cultures we seek to influence before beginning a change process. The concept of “readiness for change” refers to the degree to which an individual or group is prepared to engage in a change process. As a change agent, it is important to assess readiness for change before putting effort into a process for which the target group is not ready. The interventions that we are implementing at CU are relatively sophisticated and intensive; they would be difficult to implement in departments in which faculty had never had any experiences with evidence-based teaching, active learning, and collaboration with respect to the department’s education mission. At CU, the Science Education Initiative (SEI), the discipline-based education research (DBER) community, and the Learning Assistant (LA) program have laid groundwork that has served to ready departments for our interventions.

The Science Education Initiative provided funding and support to departments at CU to engage in course transformation. Specifically, it funded postdoctoral Science Teaching Fellows (STFs) to help faculty set learning goals, create assessments, and implement transformed pedagogies for their courses. Many of these activities involved groups of faculty working together; for example, STFs facilitated meetings of faculty to develop consensus learning goals for courses in certain departments. The SEI operated in seven CU science departments over the course of five years, ending its operations in 2013. The three departments that we discuss in this paper were all prior recipients of funding through the SEI.

Additionally, CU has a thriving discipline-based education research (DBER) community, which has been enhanced by the participation of STFs over the last five years. This community consists of tenure-track faculty, full-time instructors, postdocs, graduate students, and others who conduct education research either as their primary scholarly activity or alongside their main research area. The DBER community has done a significant amount of work independent of the SEI to transform educational practices in their departments. The three departments featured in this paper all have participants in the DBER community.

Finally, the Learning Assistant (LA) Program has had a transformative effect on STEM courses at CU. In the LA model, undergraduates are hired as LAs to assist interested faculty members in redesigning their courses to use more active learning pedagogy. The LAs then support the faculty members in the classroom by, for example, interacting with students during small-group discussions. The introduction of LAs has led to many examples of transformed teaching practices at CU. Two of the departments in this paper currently have LAs in some of their classes.

It is doubtful that departments at CU would be in such a ripe state for participation in our change efforts if not for the prior work of the SEI, DBER community, and LA program. However, we argue that none of these is sufficient to create the degree of cultural change that we are attempting with our change efforts. As a loose community of researchers, DBER’s collective activities mostly consist of a weekly seminar and informal collaborations, which are not designed to create broader change at CU. The LA Program’s efforts can be quite impactful for particular faculty members and the courses they teach, but there is not an explicit focus within the LA model on shifting departmental culture as a whole. The SEI has been instrumental in bringing CU science faculty together to implement active learning strategies, many of which have become normalized to greater or lesser extents. However, there is no guarantee that any of the SEI’s changes are permanent; rather, there is anecdotal evidence that erosion of these reforms has already begun in certain cases. Indeed, two of the three departments with which we are working see their participation with us as a way to continue the transformations begun by the SEI rather than backsliding.

In summary, the SEI and DBER communities have had a significant positive impact on education at CU that has focused primarily on faculty and individual classrooms. We view this work as necessary but not sufficient to engender deep departmental cultural change with respect to STEM education. However, this work has been instrumental in readying departments to participate in our
more in-depth cultural change efforts, and thus improving our chances of success.

D. The Outside-In Strategy

The outside-in strategy combines efforts at the faculty and administration levels to shift departmental culture towards alignment with our core commitments. While either effort in isolation is unlikely to work, we believe that the combination of the two is much more likely to be effective: a change strategy that tries to shift faculty towards more progressive beliefs and practices must be accompanied by appropriately progressive shifts in institutional policy in order for either to be effective.

1. The Faculty Level

Our work at the faculty level has shifted since we began this project. Initially, a project team member met with faculty members teaching large-enrollment gateway STEM courses in several departments. These meetings were designed to help faculty articulate learning goals for their courses and to develop a plan for assessing whether they achieved one or more of their goals that semester. Ideally, this discussion would have resulted in the collection and interpretation of data related to the goal with the help of one of our team members. The motivation for taking this approach was based in social cognition theories: if we could confront faculty with a mismatch between their goals and the actual outcomes of their teaching, we could use this dissonance to motivate them to change their teaching practices. However, we found that in practice many faculty members had difficulty articulating clear, measurable learning goals, and even for those that could, it was difficult to arrange enough time to carry out a plan to determine whether or not they were being achieved. While we learned quite a bit about various departments and courses through these interactions, they did not help us achieve our larger goal.

Based on these initial experiences, we decided to shift from working with individuals to working with teams of faculty members, which we call Departmental Action Teams (DATs). DATs consist of about six participants from a single department working collaboratively to address an educational issue relevant to the department as a whole (rather than, e.g., a single course). As in a faculty learning community (FLC; [58]), DAT participants self-select into the group and have agency to choose the educational issue they will address. DATs differ from FLCs insofar as they focus on a common, shared project in a single department rather than individual projects in multiple departments.

The name “Departmental Action Team” was very deliberately chosen. We chose “Departmental Action Team” rather than “Faculty Action Team” (or “Student Action Team”) to indicate that anyone from a given department could in principle be part of the team. The word “Action” is a reminder that the purpose of the group is to get something important done—the department should be materially different after the DAT has finished its work than it was before. Finally, this group is a “Team,” not a committee. Teams consist of a group of people working towards a common goal in which they will either succeed or fail together, with members placing the group’s goals above their own personal goals and decisions being made via consensus. On the other hand, committees consist of groups of people who often place their own goals or the goals of their “constituency” above the goals of the group; committee decisions involve compromise rather than consensus and committee work often involves talking about whether to do something rather than doing it.

The DATs that we formed met every other week for an hour; they will continue throughout the current academic year. They are co-facilitated by two members of our project team, who provide logistical support (e.g., scheduling, note-taking), an outsider perspective on the department, and guidance to keep the team from behaving like a committee. Each DAT has the explicit goal of creating a deliverable product or improvement by the end of the academic year. From the perspective of our project’s overarching goal, DATs are a way to create local cultural change among a subset of a department’s faculty that can then spread beyond that subset.

The local cultural change engendered by the DATs is aligned as much as possible with our core commitments (C1-C6). The memberships of the DAT’s are diverse in terms of gender and rank (including tenure-track faculty, non-tenure-track instructors, and, in one case, a post-doc), although they are not racially diverse given the demographic constraints of the Boulder faculty (C6). We considered the possibility of including students as full DAT members (C1), but this did not happen due to faculty discomfort with the idea. However, we will likely convene student focus-groups as a means of providing DAT participants with student perspectives, and we will try to add students as members in future iterations of the DATs. Each DAT started with an activity in which participants jointly constructed a set of outcomes that they desired for their majors; these outcomes have shaped the work of the DATs (C2). The DAT facilitators work to support collaboration and teamwork within the group (C4), to provide the group with access to data that it needs to make decisions (C3), and to make sure that conversations include big-picture, systemic thinking (C5).

Despite the short time that they have existed, our experiences facilitating the DATs leads us to believe that they are more effective than continued one-on-one work would have been. One practical reason for this is that the ability to interact with many faculty members at once in a group setting means that our resources and attention are spread less thinly than if we were meeting with each of those people individually. Beyond this, DATs embed individuals in a community of peers that interact regu-
larly in the context of education. Studies have shown that physics faculty make the decision to transform their instructional practices due to direct, personal contact with other physicists \[47\]. Therefore, the repeated contact with colleagues facilitated by the DAT’s has the potential to be transformative in how DAT participants behave as educators. This is essentially a social cognition view of change: the DAT provides an opportunity for faculty members to revise their unconscious views and prior beliefs through group learning, data analysis, and sensemaking. Because the DAT participants self-select into the group, they are more likely to be open to such changes (i.e., their change is more likely to be first order rather than second order).

A DAT can also be understood through political theories of change. The changes championed by a DAT will likely be unpopular with some of the DAT participant’s colleagues. Hence, the DAT will be more likely to succeed if it works with the existing departmental governance structures (e.g., securing the support of the department chair and collaborating with the department teaching committee). Additionally, because the DAT involves a group of people, it has more personal connections to leverage than any individual participant for building a coalition of supporters outside of the DAT. This base of support can help the DAT to implement changes and reach a level of stability such that it continues to exist after AAU support is withdrawn. Finally, if the DAT can demonstrate its value to the department, it could become institutionalized as part of the departmental governance structure. This is why it is essential for the DAT to produce a deliverable that is valuable to the department in a timely fashion.

Finally, cultural theories of change are relevant to the formation and success of the DATs. We are using an existing departmental “ritual”—committee meetings—to support DAT formation. Because committees are accepted parts of departmental culture and because DAT’s look superficially like committees, it was relatively easy to convince departmental leaders to allow us to create a DAT. Additionally, the DAT participants are encouraged by the facilitators to consider departmental values and norms as they develop the changes that they would like to see the department make; aligning messages about their proposed changes with these values will make them more likely to be widely supported by the department.

One of our hopes for the DAT’s is that they can shift the cultures of their departments into better alignment with our core commitments, essentially converting a local cultural change (within the DAT) to a global one (within the entire department). If a DAT operates according to the core commitments and its department takes up its output, then the departmental culture as a whole may shift towards better alignment with the core commitments.

2. Activities to Date

To date, DATs have been implemented in two departments: the Transfiguration Department and the Potions Department.

In the Transfiguration Department, we conducted nine one-hour interviews with individual faculty members about their teaching and their perceptions of the department; we also engaged in one-on-one consultations with two faculty members as part of our pre-DAT implementation of the faculty level intervention. These encounters provided us with significant “insider information” about the department. The Transfiguration Department was created about 10 years ago from components of two other departments. As a result, it is spread across multiple buildings on two campuses. This led many of the faculty we interviewed to report feeling isolated; many of them rarely interacted with their colleagues outside of faculty meetings. Political theories would suggest a need for coalition building in this situation, which is one function of the DAT.

The SEI had a significant impact on the Transfiguration Department by helping to develop learning goals and reformed pedagogy in all of its lower division and about half of its upper division courses. Faculty in the Transfiguration Department tend to “own” courses for many years, and the lower division courses all have multiple faculty assigned to them because of their size. Hence, the work supported by the SEI was carried out by a committee of faculty members for each transformed course, and many (but not all) of the faculty currently teaching a given transformed course were on the relevant course committee before SEI support ended. Additionally, many of the department’s full-time instructors became heavily involved in scholarly teaching as a result of the SEI, including publishing and presenting on their teaching innovations. Many members of the department, including departmental leaders, are proud of the innovations made possible by the SEI; they view their department as being on the forefront of educational innovations for Transfiguration Departments nationwide. One concern we repeatedly heard was fear that the loss of formal SEI support would lead to backsliding in the educational progress the department has made since its founding. Hence, we were able to use many aspects of the department’s existing culture—committees to enact course transformation, the practice of scholarly teaching, pride in educational innovation—to frame the change effort we were proposing, as recommended by cultural theories.

In creating the Transfiguration DAT, we heavily relied on the advice of political theories through coalition building and using existing department power structures. We met individually with a subset of the faculty we had already interviewed to get their input into how best to set up a DAT in their department. We chose to meet with faculty who seemed like they would be open to the idea of participating in the DAT. We then met with the department chair to formally propose the idea. She se-
cured the sanction of the department teaching committee for the DAT to exist and announced the formation of the DAT at a faculty meeting. In alignment with scientific management theories, she also provided incentive for participating in the DAT by offering service credit for all members of the DAT as well as a course buyout for one instructor.

The Transfiguration DAT consists of six faculty members (two tenured professors, three full-time instructors, and one retired instructor), who we either interviewed or who were encouraged to join by someone we interviewed. The main focus of the DAT is on coherence across the Transfiguration curriculum. In particular, the DAT participants want to address the problems that: (1) Transfiguration faculty sometimes do not follow the learning goals established by the SEI, so that students have not learned the material expected of them in subsequent courses, (2) faculty often do not know what goes on in courses other than the one they “own”, (3) students do not obey the prerequisite structure when taking courses, and (4) the curriculum does not explicitly address non-content outcomes for students such that they understand the nature of science, can conduct scientific research, and can communicate science to their peers. They are currently exploring methods for solving these problems, such as (1) forming a “super-committee” of the faculty who teach all of the introductory Transfiguration courses so that they can work on aligning their curricula and (2) creating a document to map the interrelation of all of the Transfiguration course learning goals so that faculty will know how their course is related others. The work of the DAT thus far is well-connected to some of the core commitments in that it exhibits a focus on learning outcomes that go beyond content (C2), teamwork and collaboration (C4), and systemic thinking across the curriculum (C5).

In the Potions Department, we had much less pre-DAT contact with the faculty than we did in the Transfiguration Department. We met with six faculty members who were teaching four large-enrollment, introductory Potions courses at the beginning of the spring 2014 semester for one-on-one consultations. We were unable to maintain contact with these faculty members with one exception: one of them contacted the AAU project team, unprompted, several months later to discuss his concern over the high failure and withdrawal rates in the introductory Potions course he was teaching. This prompted us to begin working with this faculty member to collect and analyze data to understand which students were doing poorly in these courses and why.

In parallel to this, we began to gather information about the department from informal conversations with members of the department. The Potions Department has had a relatively long history of educational reforms, which began in their introductory courses and moved to their upper division courses with the support of the SEI. However, Potions faculty members rotate through courses frequently, so there is no guarantee from semester to semester that various reforms will be used. In practice, the introductory course reforms are fairly stable from semester to semester, but the upper division courses vary wildly in terms of what reformed practices are used.

As with the Transfiguration Department, political theories guided the ways in which we approached the department. To create the Potions DAT, we met with the department chair and pitched the idea. The chair was receptive and invited us to present at a faculty meeting to recruit faculty to participate, thus legitimizing our request in the eyes of the faculty. Six people ultimately joined the DAT: three tenured professors, two untenured professors, and a postdoc. One of the tenured professors was the faculty member that contacted us about failure and withdrawal rates, so he was already inclined to work with us. However, we had no contact with the other four professors until they expressed interest in joining the DAT after our presentation at the faculty meeting.

The main area of focus of the Potions DAT is the under-representation of certain groups among Potions majors, particularly women. Anecdotal evidence suggests that the fraction of female Potions majors at CU is less than the national average, but the department has no systematic data to determine whether this is true, and if it is, whether it is an issue of recruitment, retention, or both. The DAT is in the process of making a data request to CU’s Office of Planning, Budget, and Analysis (PBA) office in order to better understand the nature of issues surrounding recruitment, retention, and representation of Potions students. DAT participants are also considering a survey of their colleagues to get information that IR will not have, such as which undergraduates did research projects in the Potions department. Hence, this DAT is also well-aligned with a subset of the core commitments in that its participants have an explicit focus on diversity (C6), want to analyze data to inform their understanding of the current status of underrepresented students in the department (C3), are thinking systemically about the reasons for the underrepresentation of students, from admissions to graduation (C5), and are working as a collaborative team (C4).

3. The Administration Level

At the administration level, the outside-in strategy focuses on shifting university incentive structures and resources. At most research universities, there is little incentive for faculty to invest the time and effort required to teach effectively, because such investment is viewed as conflicting with research productivity. Our strategy involves working with a variety of institutional structures to: (1) prioritize evidence-based, active learning teaching practice over other forms of teaching and (2) provide resources for faculty, departments, and administrators to do so.

Our work at this level is somewhat more strategically opportunistic than that at the faculty level: we have moved forward with some pre-planned interventions
while keeping alert for unforeseen opportunities to advance our goals. Because our team consists of three faculty members and two postdocs, we do not have the authority to, e.g., mandate policy changes. Instead, our main planned activities, which we elaborate below, are (1) working with the Boulder Faculty Assembly (BFA) to create a framework for teaching excellence, (2) working with the provost and other senior administrators to require evidence of teaching effectiveness in tenure and promotion (T&P) cases, and (3) working with the Office of Information Technology (OIT) to create visualization tools for analyzing data on student progress through CU. Opportunistic activities have included leveraging connections with other multi-campus institutions (like the AAU) to put pressure on CU to shift its teaching practices and reward structures.

Our efforts at this level align with our core commitments in a weaker fashion than in the faculty level. Requiring evidence of teaching effectiveness and creating tools for student data visualization will encourage evidence-based educational decision (C3). However, the “levers” that we have been encouraging the administration to push affect individual faculty; none of them directly reward departmental alignment with the core commitments. Nevertheless, the changes that administrators create that impact individual faculty can provide them with the time and incentives to contribute to the development of the other core commitments in their departments.

*Scientific management* theories are particularly relevant to our efforts at the administrative level, because they predict that changing faculty incentive and reward structures can lead to changes in faculty behavior. Of course, the danger of changing incentives in an unthoughtful way is that departments and faculty can learn how to game the system or just go through the motions, defeating the purpose of the changes. Hence, *cultural* theories also need to be brought to bear: changes to incentive structures must align sufficiently with departmental values that they will be taken up appropriately. One way to make this alignment more likely is to develop policy frameworks that departments can interpret in their own contexts; we describe an example of this below.

The focus on demanding evidence and providing access to data in the administration level aligns with *social cognition* theories by providing tools for organizational learning and sensemaking. These tools can then be used by the DATs in the faculty level to inform their work and convince their colleagues of the value of any changes they may propose.

Finally, both *political* and *institutional* theories can help guide our project team in its interactions with the administration. Political theories remind us that we have to be extremely cognizant of internal power structures as we try to convince different administrators to make changes aligned with our goals. Building a coalition of supporters is important, especially if they head key university committees or offices. Institutional theories suggest that we should align with external bodies that are applying pressure to CU in ways that are beneficial to us. If possible, we should amplify that pressure. Additionally, cultural theories imply that it will be easier for us to influence administrators if we align our messages with issues that are already administrative priorities; student retention is a particularly salient example at CU.

### 4. Activities to Date

As suggested in the previous section, our work at the administration level has taken many forms, which we describe here.

Through our work with the chair of the Boulder Faculty Assembly, the BFA has shifted nomination requirements for its campus-wide Award for Excellence in Teaching to require “evidence of the candidates teaching effectiveness or innovation,” including “impact on student intellectual development,” “evidence of student engagement,” and “enriching the scholarship of teaching and learning” [71]. While this change only directly impacts a few award recipients, it signals to the broader CU faculty that the BFA values student outcomes, evidence, and scholarship when it comes to teaching. Shifting this incentive makes sense from the perspective of *scientific management* theories. Additionally, we are working with the BFA to create a Framework for Teaching Excellence that would be adopted and contextualized by individual departments to shift their promotion and tenure guidelines with respect to teaching. Once this Framework has been accepted by enough departments, we will then work with the senior administration to require evidence of student learning in T&P decisions in alignment with the Framework. Again, this shifting of incentives is aligned with scientific management theories, but in this case *cultural* theories also play a role. By allowing each department to interpret the Framework with respect to its own norms and values, there is a higher chance that it will be widely accepted.

We are working with the Office of Information Technology to implement new data visualization tools to assist decision-makers at CU (especially department chairs) in analyzing student data. In particular, these tools visualize student “pathways” through the curriculum, allowing a department chair to see how long her majors take to graduate, what their demographic breakdown is, whether there are particular courses that cause them to switch majors or drop out of CU, and so on. These tools are currently in development (some of the leaders of the Potions Department provided initial user feedback). The availability of these tools aligns well with *social cognition* theories: the more data department leaders have about what is actually happening to their students as they proceed through CU, the more likely they will be to see inconsistencies between reality and their perceptions of reality and act on those inconsistencies by initiating positive change.
Retention is a major issue of concern among CU’s senior administration, with current estimates of freshman dropout rates at about 20%. In response, the Division of Academic Affairs created a persistence taskforce to generate recommendations on how to increase retention for the consideration of the Provost. One member of our project team was appointed to this taskforce, and he was able to convince the group to include two recommendations that align with our core commitments: (1) enhance the prestige, respect, and reward structure for excellence in scholarly teaching and (2) develop user-friendly software designed for department chairs to access student data. This is a classic application of political theories. Our project team member was able to use his network at CU and existing power structures to make sure that our agenda was represented in an important channel of communication to the Provost.

Finally, our project team has forged connections with external university coalitions whose missions are aligned with our goals; this is an example of applying institutional theories. The AAU is an obvious example of such a group, since they are funding this work. Their prestige among American research universities has influenced administrators to pay more attention to our efforts than they otherwise might have. We also convinced the appropriate administrators to support CU in joining the Bay View Alliance (BVA), “a consortium of research universities carrying out applied research on the leadership of cultural change for increasing the adoption of improved teaching methods at universities” [72]. The BVA conducts research on several areas which are aligned with our goals, including transforming introductory courses, developing students’ cross-disciplinary intellectual skills, and using data analytics. Collaborations between CU and other BVA universities in these research areas will increase their importance on campus.

E. The Middle-Out Strategy

Our second change strategy is the middle-out strategy, which focuses on directly shifting the culture of a department towards alignment with our core commitments through a systemic, long-term change process. Large-scale cultural change processes of this type have been modeled and implemented in the context of business organizations for decades [9], but this work has not been applied to academic departments in a systematic way. Hence, our efforts to do so will be challenging since we lack examples in higher education to emulate. However, there are effective change processes that have been successful in systems similar to academic departments that we can adapt [73]. Our change process will involve five components (which will not necessarily occur sequentially):

- Developing a department vision: A vision is not simply a mission statement, but a set of purposes to which faculty are willing to commit. We take our six core commitments as a starting point for creating a shared vision, but allow for the department to build upon and interpret them within their local context (consistent with cultural theories). In essence, our core commitments lay out basic parameters for what the collaborative change process might achieve.

- Revising assumptions about teaching and learning: Through individual faculty interviews, we create mental maps of their beliefs around teaching and learning. The maps help identify areas for productive change efforts and also barriers to faculty embracing their shared vision. The mental maps are also tools for intervention: by sharing them with the faculty, we can reveal assumptions and incongruities of which they were not previously aware, thus spurring learning. By actively supporting faculty through this process, we can encourage second order changes, consistent with social cognition theories.

- Developing capacity to meet learning goals: Capacity-building first requires the identification of key barriers to meeting learning goals. These barriers can then be overcome either by redistributing existing resources or seeking out additional support where it is required.

- Integrating teaching and learning goals systematically with research and other departmental functions: This step requires a shift in how teaching is viewed: not simply as an “add on” but as equally important to other departmental activities and a meaningful part of the scholarly practice of faculty members. Capacity-building and revising mental maps can help with this process.

- Developing a collaborative process for continuous assessment and innovation: Issues of teaching and learning are never simply “solved,” thus, improvement has to become an ongoing departmental function. Developing such a function provides opportunities for continued faculty development and continually-improving educational assessments and practices.

Overall, this process has the potential to increase the department’s capacity and success not only with respect to its teaching mission but also more broadly if it applies the lessons it learns to its research and service missions as well.

For a change process like this to work, the target department must be open to innovation and ready to change. Departmental buy-in is essential; a meaningful change process cannot be forced upon members of an unwilling department. Thus, a crucial first step is to identify a willing department. If no such department exists on a given campus, one possibility would be to start with the outside-in strategy and use it as a mechanism for readying a department to undertake the middle-out strategy.

The activities associated with this change process will help to shift faculty beliefs, encouraging them to become more aware of competing mental maps and to develop a more productive understanding of their role in student learning. As a result, appropriate student outcomes will emerge without being externally imposed as faculty shift their practices to align with the new culture they are co-
creating. This shift in culture also has the potential to impact the administration; for example, if the department decides that it needs to alter the way it evaluates teaching in T&P decisions, it will have to work with the administration to ensure that these changes will not harm its faculty members’ chances for tenure when their tenure cases come up before a university-wide personnel committee. Thus, shifts in department policies could encourage similar shifts in university policy. These changes on both the faculty and administration levels can then further influence department culture, creating a sustained feedback cycle. Thus an approach that focuses on the department has the potential to impact all parts of the university.

We anticipate that a change process of this type would last between one and two years. The process would involve, at minimum, a one-to-two day departmental retreat to develop a vision, mental maps, assessment criteria, and a process for moving forward that would include 30-day, 90-day, and one-year goals. The retreat would establish working groups to complete different tasks (e.g., establishing learning goals for the major, creating a more supportive environment for innovations and positive relationships, and revising reward systems). At regular intervals, the department would meet to assess progress, reflect on successes and lessons learned, and adjust its plans. The members of our project team will be involved as facilitators of this change process.

This change process heavily relies on social cognition, cultural, and political theories of change. In order for the process to be successful, faculty have to undergo second order change. Thus, social cognition approaches are essential for uncovering mental maps and encouraging group learning and sensemaking. Additionally, this process must be sensitive to the existing culture of the department so that it does not depart too quickly from existing values, norms, and rituals as it tries to create new ones. Finally, as change agents our team has to be aware of the existing interpersonal relationships within the department so that we do not inadvertently damage these relationships and fracture the department.

1. Activities to Date

We are going implementing the middle-out strategy in the Herbology Department, a relatively low-conflict department with a high degree of commitment to education. This department worked with the SEI to redesign its three large-enrollment core courses; course transformation focused on defining “core ideas,” introducing active-learning activities, using clickers and case studies, and engaging students in higher-order cognition and metacognition. Herbology also committed significant SEI resources to implementing learning assessments and peer observation tools. They currently have one year of SEI funding remaining.

Our contact with the Herbology Department has primarily been through members of the departmental leadership (as suggested by political theories), including the chair and a senior faculty member who has been championing Herbology’s involvement with the AAU initiative (and who is the departmental director for Herbology’s SEI efforts). These faculty members believe that the department will be very receptive to participating in the change process, although they predict some initial skepticism. In order to gauge interest, they surveyed their colleagues. Of the 13 respondents (out of 33 faculty members), 12 indicated that they are “genuinely” or “very” interested in the AAU change effort. Perceived benefits reported on the survey included the potential to continue the transformations initiated by the SEI, to create better teaching experiences for both students and professors, and to gain greater recognition of collective and individual teaching efforts. All of this evidence strongly suggests that the Herbology Department is ready for a change process as intensive as the one we proposed.

The timeline for the change process has been relatively slow and deliberate. We began conversations with the appropriate Associate Dean in the spring semester to be sure that she would be supportive of Herbology entering into this process. After her support was secured, including a financial commitment, conversations proceeded with the Herbology chair and “champion.” Our team eventually met with Herbology’s executive committee and presented our proposal at a faculty meeting. After several faculty votes, the department unanimously agreed to engage in the change process. Under the most aggressive scheduling, the change process described above will commence in January 2015 with a departmental retreat.

Our preparations for the retreat align with social cognition theories. We are planning on issuing a survey to the Herbology faculty and conducting a series of individual interviews. Both the survey and interviews are designed to determine the degree to which the faculty see various parts of our core commitments as important to the future of the department and as already present in the department. The surveys also ask about faculty members’ hopes and concerns with respect to the change process. The interviews dive deeper than the surveys; thus, they will be instrumental for the initial development of mental maps. All of this data will be formative both for the project team in designing the retreat and subsequent activities and for the Herbology faculty in beginning to understand their assumptions about education. The data will also serve as a baseline that we can use to track the department’s progress in shifting its culture.

As an additional formative and summative cultural assessment, we are currently revising the PULSE Vision and Change rubrics [74] to capture shifts in departmental culture. The PULSE rubrics assess department alignment with the recommendations of the 2011 report Vision and Change in Undergraduate Life Science Education: A Call to Action, including sections related to curriculum alignment, assessment, faculty practice and sup-
port, infrastructure, and climate for change. Our modifications to the PULSE will result in a more streamlined instrument aligned with our core commitments. It will serve both as a measurement tool for pre/post testing of department culture as well as a formative intervention tool for facilitating group discussions around cultural aspirations.

F. Summary of Activities

To summarize, we have embarked on an ambitious effort at CU to promote departmental cultures that value evidence-based, student-centered, outcomes-focused educational experiences for their undergraduate students that are driven and sustained by active faculty collaboration and continuous improvement processes. To these ends, we have implemented two strategic approaches—the outside-in and middle-out strategies—that are grounded in theories of change derived from the organizational change literature. These are based on a model of the university that singles out the department as the appropriate focus for a cultural change effort while recognizing the need for a holistic approach because of the interconnected nature of the university as a system. While these strategies may work independently (a study we are conducting currently), we anticipate that they work best in conjunction. This model and associated strategies are adaptable to local circumstances at just about any institution of higher education.

IV. CONCLUSION

The need for cultural change with respect to the educational mission of STEM departments is more urgent than ever. Nevertheless, experience has shown that many of the most prevalent strategies for effecting change do not work as well as intended, for at least two reasons:

1. Most change efforts ignore the complex, interrelated nature of universities and the fact that change efforts must be designed to effect second order change.

2. Higher education change agents are largely unfamiliar with the vast organizational change literature and therefore do not take advantage of the theories of change that this literature has produced.

We address these two problems by developing change strategies that designed to impact departmental culture and that are grounded in theories of change from the organizational change literature. Our two synergistic change strategies aim to shift departmental cultures to be in better alignment with six core commitments that lead to a collaborative, student-centered, evidence-based educational environment. Our two strategies address the university ecosystem as a whole and can be in conjunction to effect systemic, sustained reform in STEM departments. These strategies may be used simultaneously or sequentially; for instance, initial success with the outside-in strategy might prompt a department to seek a more holistic change process through the middle-out strategy. As we continue to study and implement our strategies, we hope to validate and refine them, providing productive starting points for change efforts at other institutions.

ACKNOWLEDGMENTS

We thank the Association of American Universities and the Helmsley Charitable Trust for funding this work.

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