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The role of leadership in educational innovation: a comparison of two mathematics departments' initiation, implementation, and sustainment of active learning

Rachel Funk[1] · Karina Uhing[2] · Molly Williams[3] · Wendy M. Smith[4]

Abstract

Several studies have shown that the use of active learning strategies can help improve student success and persistence in STEM-related fields. Despite this, widespread adoption of active learning strategies is not yet a reality as institutional change can be difficult to enact. Accordingly, it is important to understand how departments in institutions of higher education can initiate and sustain meaningful change. We use interview data collected from two institutions to examine how leaders at two universities contributed to the initiation, implementation, and sustainability of active learning in undergraduate calculus and precalculus courses. At each institution, we spoke to 27 stakeholders involved in changes (including administrators, department chairs, course coordinators, instructors, and students). Our results show that the success of these changes rested on the ability of leaders to stimulate significant cultural shifts within the mathematics department. We use communities of transformation theory and the four-frame model of organization change in STEM departments in order to better understand how leaders enabled such cultural shifts. Our study highlights actions leaders may take to support efforts at improving education by normalizing the use of active learning strategies and provides potential reasons for the efficacy of such actions. These results underscore the importance of establishing flexible, distributed leadership models that attend to the cultural and operational norms of a department. Such results may inform leaders at other institutions looking to improve education in their STEM departments.

Keywords Active learning · Institutional change · Calculus reform · Undergraduate mathematics · Case study

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Rachel Funk, Karina Uhing, and Molly Williams have contributed equally to this work, and are thus ordered alphabetically as first author.

✉ Wendy M. Smith
wsmith5@unl.edu

Extended author information available on the last page of the article

Introduction

University leaders are increasingly concerned with student retention, graduation rates, and overall student success. Of particular concern are student experiences in STEM courses; research has shown that such experiences may negatively impact the persistence of students in both STEM and non-STEM majors. These issues are directly connected to students enrolled in mathematics courses (Ellis et al. 2016; Moreno and Muller 1999; PCAST 2012). In the United States, roughly 94% of enrollment in college mathematics courses (over two and a half million students per year) is in courses at the Calculus 2 level and below (Laursen 2019), and historically, it is not unusual for first-year mathematics courses to have DFW rates (grades of D, F or Withdraw) exceeding 30–40% (CRAFTY 2007). More recently, the Progress through Calculus Team surveyed over 200 PhD and masters granting mathematics departments in the United States about various features of their programs, and found that DFW rates were, on average, 27% for Precalculus courses, 22% for Calculus 1, and 20% for Calculus 2 (Apkarian and Kirin 2017). Therefore, focusing on improving student success in Precalculus to Calculus 2 (P2C2) has the potential to impact a large number of students.

Student-centered instructional practices, such as using active learning strategies, have emerged as a way to increase student success in STEM fields, addressing not only student learning, but also student attitudes, beliefs, motivation, and goals (e.g., Freeman et al. 2014; Theobald et al. 2020). Although much more is now known about effective instructional practices and campus structures to support student success, institutes of higher education are slow to change (Kezar 2014), and professors have not widely adopted such research-based practices (Smith et al. 2021; Stains et al. 2018; Tatto et al. 2018). In many countries, lecture is still viewed as the most effective pedagogical practice for collegiate instruction (e.g., Tatto et al. 2018, 2020). Indeed, since such instruction typically proved effective for collegiate instructors themselves, it can be easy to assume lecture-based instruction should work for all students. Yet, this is not the case: lecture-based instruction can exacerbate opportunity gaps (Theobald et al. 2020). However, some professors are becoming more aware of the benefits of active learning and are making attempts to incorporate such strategies into courses (Laursen 2019). In a summary of the Progress through Calculus report, Rasmussen et al. (2019) highlight that 91% of mathematics departments consider active learning strategies to be very important or somewhat important in precalculus and calculus courses, yet only 15% reported that they are very successful in using such strategies. Similarly, in a survey of 722 physics professor across the United States, most reported that they were familiar with active learning strategies, yet the use of such strategies is frequently abandoned (Henderson and Dancy 2009). Professors shared numerous reasons for abandoning active learning strategies. Such reasons include not being able to see a difference in student learning gains, concerns about how much time such strategies take, having to teach a larger class, and having an unsupportive department. This suggests that professors need additional development and external support to permanently integrate such strategies into their instructional practices.

The process of changing one's instructional practice from lecture-based to student-centered is complex; it requires more than just adopting a new technique such as think-pair-share. To support student learning, instructors need to use strategies that both provide opportunities for students to communicate their reasoning, and use this reasoning to develop ideas in class discussions (e.g., MAA 2018; Smith and Stein 2018; Speer and Wagner 2009). Speer and Wagner (2009) suggest that professors, even those with extensive teaching experience, may struggle to carry out student-centered techniques because they require specialized knowledge to enact; such knowledge differs from the knowledge used when enacting traditional teaching methods. Instructors who do not have the support to learn this type of knowledge may struggle to enact such strategies in ways that support student learning and conclude that such strategies are not an improvement. Without external support, such instructors are likely to revert to using traditional teaching methods. Beyond the challenges posed by learning new instructional practices, the use of student-centered instruction involves a parallel need to develop or select new instructional materials that align with these methods (e.g., syllabi, pacing guides, textbooks, assessments, etc.). Such changes are time-intensive, and in many departments such materials are shared. This means that individual change efforts do not exist in a vacuum; rather instructors often need the support and commitment of their department when making lasting changes to their instructional practice (Elrod and Kezar 2016).

Although some efforts to change instructional practices occur at an individual level, these initiatives often involve a community of individuals in a department who are all dedicated to change. Department members hoping to influence and transform shared instructional practice norms need to focus their efforts beyond the course level. These change efforts necessarily include a focus on classroom instruction; however, reforms that ignore the "political and institutional conditions required for long-lasting change" (Tobias 2000 p. 103) are unlikely to succeed or be sustained. Change initiatives need to address departmental and institutional barriers and have significant support at the department, campus, and community levels (Elrod and Kezar 2016). Lack of widespread support for such efforts will undermine them (Kezar 2014). Thus, it is important to study leadership decision-making and the leaders who are directing and supporting these efforts to understand how they make changes that span multiple levels.

Often, leadership decision-making related to these improvement efforts is seen as either "top-down" or "bottom-up," signifying the origins and direction of decisions. Martin (2003) discussed how this either-or dichotomy often leads to misalignment of goals from both approaches. In the context of equity, he argues:

> Rather than responding directly to the needs of marginalized students and centering discussions around what is best for these students, policy makers and mathematics educators have decided what (valued) mathematics should be learned, who should learn this mathematics, and for what purposes equity in mathematics is to be achieved. (p. 12)

He further suggests that top-down conceptualizations of equity led to interventions that were "out of alignment with the inequalities experienced by

underrepresented students, parents, and communities" (Martin 2003 p.12). Since then, more research has come out to support the claims that top-down leadership is common (e.g., Henderson et al. 2011), and that there is a need for more "bottom-up" or grassroots leadership (e.g., Spillane and Diamond 2007). Kezar (2012) acknowledges that this dichotomy can be contradictory, but it also could be a hidden opportunity for strategic convergence between the two approaches, and the model of distributed or shared leadership is one common way this convergence can be achieved. Prysor and Henley (2018) studied higher education environments in the United Kingdom and similarly identified boundary-spanning across top-down and bottom-up efforts as necessary to launch and sustain institutional transformation efforts. To address the gaps between what research has shown to be effective practices and actual instructional practices in higher education, this study seeks to identify change mechanisms that allow institutions to implement and sustain active learning in first-year mathematics courses.

Background and context

This study involves two cases of large research universities in the United States that have incorporated active learning into their calculus sequence courses via a comprehensive approach to cultural and instructional change. We use Laursen and Rasmussen's (2019) definition of inquiry-based mathematics education to form our definition of active learning: (1) students learn mathematics by engaging in challenging, cognitively demanding tasks; (2) students routinely communicate (orally and in writing) their own reasoning and engage with the reasoning of others; (3) instructors attend to and make use of student thinking to advance the mathematical agenda; and (4) instructors are explicitly attending to issues of diversity, equity, and inclusion. Although not explicitly labeled "active learning," these principles are also embodied in the recommendations of the Mathematical Association of America's recent *Instructional Practices Guide* (2018). It should be noted that in both cases, change efforts focused mostly on curriculum and uses of student thinking to implement active learning strategies, aligned with two of Laursen and Rasmussen's pillars of inquiry-based mathematics education.

First- and second-year undergraduate courses in the United States typically include some form of precalculus level courses along with introductory level calculus courses. Calculus is typically broken up into a sequence of courses: Calculus 1 in the United States is typically understood to cover contents such as limits and derivatives, whereas Calculus 2 covers topics such as integration, sequences, and series. Almost all first-year college students in the United States take one of these courses depending on their level of preparation entering the university system. At large institutions, like the ones we studied, there are usually several sections of these courses made up of students from different areas of study (e.g., engineering, physics, chemistry, etc.). Many institutions choose to divide sections of a course up into "lecture" and "recitation" sessions. Lecture sessions typically consist of presenting new material to students, where recitation sessions are focused on reviewing content, practicing problems, and providing more

individualized help. Depending on the institution, these courses are taught by a range of instructors including graduate students, part-time instructors, and full-time professors, who are collectively referred to as faculty in the United States. In our paper, we use the term "instructor" to refer to an individual person who teaches undergraduate courses, whereas the term "faculty" refers to a group of instructors. We use this terminology throughout this paper.

The reforms that we studied started with a focus on Calculus 1, then grew to encompass Calculus 2, Precalculus-level courses, and other multi-section courses. In this paper, we refer to these courses as P2C2 courses (Precalculus through Calculus 2). This case study focuses specifically on department-level changes and the decision-making process behind such changes. In both cases, leaders worked to develop a common vision for changes among key stakeholders, which is often viewed as the foundation of effective change (Elrod and Kezar 2016). Even though both institutions had upper administrators interested in promoting student success, the decision-making process did not resemble top-down change, but rather was distributed and shared across different people of power within the department (Kezar 2012). These cases are drawn from a larger set being developed by a collaborative National Science Foundation project: Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL; DUE-1624643, 1624610, 1624628, and 1624639). SEMINAL is studying how mathematics departments successfully incorporate active learning into their calculus sequence courses and how to guide other departments looking to institute similar reforms.

Research purpose and questions

The overarching goal of SEMINAL is to identify change mechanisms that allow institutions to implement and sustain active learning in first-year mathematics—Precalculus to Calculus 2 (P2C2)—courses. The project has two phases: Phase 1 involves six retroactive case studies of institutions that have reportedly succeeded in sustaining active learning, whereas Phase 2 consists of nine longitudinal case studies of institutions who are just beginning to reform instruction in their P2C2 sequence using the support of a networked improvement community (Martin and Gobstein 2015).

The SEMINAL project's overall research question is What conditions, strategies, interventions, and actions at the departmental and classroom levels contribute to the initiation, implementation, and institutional sustainability of active learning in the undergraduate calculus sequence across varied institutions? Early work from this project has shown that leadership, in particular the commitment of formal leaders at departmental and institutional levels, is a critical driver in reform efforts (Smith et al. 2017). In this article, we focus on this key driver and compare how formal and informal leaders at two of SEMINAL's Phase 1 institutions have impacted the initiation, implementation, and sustainability of improvement efforts in P2C2 courses. Thus, our research question is

How might leaders within a department impact the initiation, implementation, and sustainability of active learning in P2C2 courses?

Conceptual frameworks

To begin, we define leaders' roles in the change process. We define "leader" broadly to include those individuals with formal or informal leadership roles who are in a position of power and/or have the respect of others at their institution. Leaders have either the authority to initiate change or the skills to motivate those with authority to do so. Hunter et al. (2007) approach leadership within a system framework that includes leaders, constituents, communication among constituencies, and contexts for those interactions. Often research on leadership includes language about subordinates; such roles and hierarchies are often less clear in education, particularly within academic departments in higher education (Hunter et al. 2007). Furthermore, leadership is not about "singular events….Rather, leadership is a process, a series of activities and exchanges engaged in over time and under varied circumstances" (Hunter et al. 2007 p. 440). Fullan (2006) claims that sustainable systems necessitate a specific type of leader: such leaders must be "system thinkers in action" (p. 114) capable of both working within the system and seeing the bird's eye view of how their work connects to the larger context. Leadership, he argues, is key to sustainability efforts.

To address how leaders sustain, as well as initiate and implement change efforts, we draw on two frameworks: Kezar and Gehrke's (2015) stages of development for communities of transformation and Reinholz and Apkarian's (2018) four-frame model for cultural change in STEM departments. Rather than presenting a chronological timeline of changes at the two universities, we use Kezar and Gehrke's stages of development (potential, coalescing, maturing, stewardship, and transformation) to organize our findings and describe the changes that occurred during the different stages of active learning reforms. At both universities, these changes also involved significant cultural shifts. In our analysis, we acknowledge that leaders exist within a cultural system and use the four frames (Reinholz and Apkarian 2018) to better understand the connections between leadership and four key components of culture: people, power, symbols, and structures. Exploring these connections also highlights the significance of our findings by helping us generalize how leaders might impact the initiation, implementation, and sustainability of active learning in P2C2 courses.

Conceptualizing the change process

Although calls for educational reforms are not new (e.g., Dewey 1902), sustained reforms resulting in student-centric teaching have been elusive (e.g., Kezar 2014; Lane et al. 2020; Laursen 2019; Reinholz et al. 2020; Stains et al. 2018). Although "bottom-up" approaches that begin with instructors have long been

Table 1 Stages in the lifecycle of a community of transformation

Stage	Features
Potential	Spend years of gestation refining approach
	Bring together key leaders who are committed to initiating changes
	Develop and refine a shared philosophy
	Acquire initial grants or resources
	Find a home to begin work
Coalescing	Identify the STEM education problem
	Connect the problem being addressed to broader movements
	Solidify philosophy into key documents
	Foster a culture around the shared philosophy, which reflects the core values of the community
	Develop structures that bring the community together and establish the community's core values
	Develop meaningful materials
Maturing	Create a trajectory for different stages of involvement in the community
	Continue to acquire new resources
	Expand the community by inviting non-members to join
	Provide opportunities for leadership development
	Identify mechanisms to bring in new leaders and distribute leadership responsibilities
Stewardship	Ensure continuity of leadership through a succession plan
	Create a viable model for preserving resources
	Establish a dedicated team of project members
	Collect feedback and advice from members
	Conduct research to assess and demonstrate the value of the community over time
	Adapt and cultivate an area of expertise and a strategic focus
Transformation	Respond to challenges by reexamining original purpose

theorized as having more potential for sustainability and impact (e.g., Darling-Hammond 1990), reforms that do not also attempt to address cultural change and power dynamics over time tend to be short-lived (e.g., Kezar 2014). Effective leadership for education innovations is a promising approach (Spillane and Diamond 2007), but little research on higher education leadership in mathematics exists (Elrod 2020; Reinholz et al. 2020).

Kezar and Gehrke (2015) define a community of transformation as a "distributed community of individuals that uses a core philosophy to create and foster new practices that can be integrated into the various institutions in which individuals work" (p. 20). In our research, the individuals involved in the reform efforts within the mathematics department at each university operate in a similar way as a community of transformation due to their shared interest in establishing innovative instructional norms among their colleagues.

Although the communities we studied were not widely distributed nor spread across various institutions, they share many key characteristics with the communities of transformation that Kezar and Gehrke identify. Like communities of transformation, these communities provided ways for individual educators to learn how to effectively enact active learning strategies, while simultaneously working to shift the culture of their department. We also found that the development of these communities paralleled the lifecycle of communities of transformation described by Kezar

and Gehrke (2015). Adapting the work of Wenger et al. (2002), Kezar and Gehrke (2015) present a framework for understanding the formation, design, and sustainment of a community of transformation. Kezar and Gehrke's (2015) framework separates the lifecycle of a community of transformation into five stages: potential, coalescing, maturing, stewardship, and transformation. We summarize Kezar and Gehrke's (2015) framework in Table 1.

For the retroactive case studies reported in this article, we interviewed people about transformative efforts from the recent and more distant past. As such, some of the finer-grained distinctions between the potential and coalescing stages and between the maturing and stewardship stages were difficult to capture precisely. Kezar and Gehrke (2015) agree that both potential and coalescing and maturing and stewardship tend to overlap in ways that can make them indistinguishable. Thus, we group the potential and coalescing stages together to discuss how reform leaders initiated and implemented changes. We also group the maturing and stewardship stages together to discuss the sustainability of these changes.

To conceptualize sustainability, we reference Fullan (2005), who describes sustainability as "the capacity of a system to engage in the complexities of continuous improvement" (p. ix). An important characteristic of sustainable systems is that leaders are continuously working to improve the system. Whereas Kezar and Gehrke (2015) describe stewardship as "making the community sustainable over time" (p. 53), our conceptualization of sustainability includes both the maturing and stewardship stages as actions taken in these stages involve the continuous improvement to initial reforms. Furthermore, we note that the communities of transformation studied by Kezar and Gehrke (2015) were formed without an initial plan for sustainability.

Our communities, however, expanded reform efforts with the goal of making changes sustainable over time. Because of this difference, it is difficult for us to distinguish between actions taken in the maturing and stewardship stages. For example, leaders at one university created a coordinator position with the specific goal of making reform changes sustainable. Although this action helped their community mature by allowing them to bring in a new leader, they also did this explicitly to ensure the continuity of leadership in their calculus program.

In addition to combining the maturing and stewardship stages, we discuss how reform leaders have responded to challenges in the change process. We view this ability to respond to challenges as an essential part of sustaining reforms. However, we found little evidence that these communities have had to re-examine and change their original purpose. Therefore, we do not explicitly address the transformation stage in our findings.

Four-frame model for understanding departmental change

Departments and faculty are more likely to invest in course improvements when the campus and departmental culture supports instructional innovation (Kezar 2014). Bergquist and Pollack (2008) suggest culture is a lens through which faculty members understand their universities: "A culture provides a framework and guidelines

Table 2 Description of the four-frame model adapted from Reinholz and Apkarian (2018)

Frame	Description
People (Human resource)	Individuals members in a department who have their own lens, goals, needs, and identities, which influence their interactions with others
Power (Political)	Explicit hierarchies or implicit status or positioning that influence how community members interact with one another and make decisions
Symbols	The shared beliefs, assumptions, and values that department members use to guide their reasoning and determine their use of structures
Structures	Observable mechanisms, such as roles, responsibilities, routines, etc., which determine how members of a community interact with one another

that help to define the nature of reality—the lens through which its members interpret and assign value to the various events and products of this world" (Bergquist and Pawlak 2008 p. 7). Culture as a lens can be a useful framework, but to capture the dynamic aspects of departmental change, additional dimensions are necessary.

Bolman and Deal's (2008) four-frame model for understanding organizations may be useful in characterizing changes at the departmental level. This model involves four frames: human resource, political, symbolic and structural. Each frame "is both powerful and coherent. Collectively they make it possible to reframe, looking at the same thing from multiple lenses or points of view… reframing is a powerful tool for gaining clarity, regaining balance, generating new options, and finding strategies that make a difference" (Bolman and Deal 2008 pp. 21–22). Although individuals tend to gravitate to a certain frame of thinking, "learning to apply all four [frames]" can deepen a leader's understanding of their organization and help them make more informed decisions (Bolman and Deal p. 18). Reinholz and Apkarian (2018) have adapted this model for use in higher education contexts to capture the subtleties inherent in departmental change efforts. Their model relabels the four frames as *people*, *power*, *symbols*, and *structures,* each of which is integral in understanding departmental culture (see Table 2 for a description of each of these frames).

Researchers have used this four-frame model as an analytic tool to understand how STEM departments are able to enact systemic changes (e.g., Rämö et al. 2019; Reinholz and Apkarian 2018; Reinholz et al. 2019). Reinholz et al. (2019) found this framing useful in describing culture shifts within one science department over the course of 15 years. They found that whereas lasting shifts seemed to have occurred when viewing the department's culture through the people, symbols, and power frames, without permanent structures in place the department's initial educational improvement efforts (which were originally deemed a success) could not be sustained. This prompted a second, more targeted, change effort that explicitly developed sustainable structures to support change efforts. The authors contend that this second wave of change efforts built on initial efforts and made change efforts more sustainable.

In this paper, we use the four frames to interpret how cultural change supporting active learning was achieved in three stages of the change process: initiation,

Table 3 Contextual features of phased change University and Long-Term University

University	Undergraduate enrollment	Department composition (Approx.)	Typical P2C2 instructors	P2C2 format
Phased change University	Approx. 30,000 undergraduates	120 members (21% full-time faculty, 20% part-time, 59% graduate students, postdocs, and other)	Graduate students and a small number of part-time instructors	Meets in small sections four days a week with instructor and one day a week for recitation for 50 min
Long-term University	Approx. 29,000 undergraduates	300 members (23% full-time faculty, 5% part-time, 72% graduate students, postdocs and other)	Postdocs, graduate students, and a small number of part-time instructors	Meets in small sections (approx. 28) three days a week for 80 min

implementation and sustainability. In particular, the four-frame model provides us with a framework for understanding how leaders addressed these frames in their efforts to support the uptake of active learning within their departments.

Methods

SEMINAL is a five-year NSF-funded mixed-methods research project studying the initiation and sustainability of active learning in mathematics in two phases. Phase 1 focused on retrospective case studies of institutions that have sustained active learning reforms for at least three years; the selection of institutions was part of the larger SEMINAL research project, and was limited to institutions that offered some type of post-baccalaureate degree in mathematics (see Smith et al., 2021, for more information). Phase 2 focused on incentivized case studies of institutions in the midst of reforms.

The findings presented in this paper draw on data from two of the Phase 1 institutions we call Phased Change University and Long-Term University; for more information about SEMINAL, the institutions, and other findings, see Smith et al. (2021). The pseudonyms "Phased Change" and "Long-Term" were selected to represent changes that were made at each institution. The mathematics department at Phased Change University had gradually made changes to infuse more active learning into their P2C2 courses over a period of several years, whereas the changes at Long-Term University had been enacted and sustained for more than a decade. P2C2 courses at both universities are coordinated courses that have common elements across all sections (e.g., common syllabus, common homework assignments, common exams). Both universities are large, public research-intensive (R1) institutions in the Midwestern United States. Table 3 presents a brief snapshot of each institution and departmental context.

Table 4 Participant counts and roles

Participant role	Phased change University	Long-term University
Upper administrators	3	4
Formal department leaders	6	4
Course coordinators	4	5
P2C2 instructors	6	11
Math center directors	2	1
Learning assistants	3	0
Students	2	1
Other STEM faculty	1	2
Total	27	28

Data were collected at site visits in Spring 2017. To collect data, a point-of-contact was chosen at each site to coordinate the data collection efforts between the research team and the site. The local contact worked with the researchers to help identify who to interview and contacted those people to set up the schedule for the site visit. During these visits, four researchers collected qualitative data in the form of interviews. Phased Change University had 16 individual interviews and 4 focus groups, yielding a total of 27 participants. Long-Term University had 9 individual interviews and 5 focus groups, also yielding a total of 27 participants. The data discussed in this paper are taken from the audio-recorded interviews with campus administrators, faculty within the mathematics department (including full-time professors, full-time instructors, part-time instructors, postdocs, graduate students, and course coordinators), faculty from other STEM disciplines, and undergraduate students. Table 4 shows a count of participants from each institution along with their roles. We analyzed data from all of these interviews to generate the findings presented below. This project followed the ethical and legal standards outlined by the Institutional Review Board for research involving human subjects. Informed consent was obtained from all individual participants in the study.

Data analysis

We transcribed each interview and coded them in MAXQDA 12. We drew initial codes (e.g., coordination, department leadership, professional development) from a guiding framework in the SEMINAL grant proposal, which was informed by Bressoud et al.'s (2015) *Characteristics of Successful College Calculus* project and institutional change literature. We also used this framework to design the project's data collection plan, including interview protocols. To ensure consistency of coding across all of the SEMINAL sites, the SEMINAL team created a common codebook with nine major codes: coordination, culture, equity, professional development, instruction, resources, department leadership, institutional leadership, and local data. (For more detailed information about each of these codes,

see Chapter 2 in Smith et al. 2021.) In addition, the qualitative analysis team decided on common protocols for tagging. To the extent we could, we included both the question and response in an excerpt. Excerpts over half a page in length or excerpts in which the interviewee discussed different topics were typically broken into shorter segments. Excerpts were tagged with multiple labels when necessary (e.g., a statement about the equitable benefits of coordination would be tagged as equity and coordination).

After interviews were transcribed, each interview was tagged using these nine codes. We also used an iterative process to generate sub-codes under each main code. At least three researchers independently coded each transcript, and then met to reconcile their codes in order to achieve complete agreement on coded segments (Creswell and Poth 2018).

After coding all interviews, we each took a main code (e.g., coordination) and extracted all excerpts with that code into an Excel file. Individual researchers then analyzed all excerpts with that code in a second cycle of analysis and constructed reports of facts and emerging themes (Creswell and Poth 2018). We then exchanged reports and codes among researchers for additional reconciliation. Using these reconciled reports and other documents provided by each site, we drafted thick descriptions for both institutions to make a side-by-side comparison for this comparative case study (Stake 1995). These thick descriptions were sent to leaders in each department, and we invited them to correct any errors and make any clarifications they saw fit to do. These revisions are incorporated into the data analysis presented below. Following our initial analysis, we sought out additional theories that could frame our findings; we determined the four-frame model (Reinholz and Apkarian 2018) to be particularly useful as an interpretive framework to organize the themes we generated and discuss the implications of our findings.

Results and discussion

In this section, we describe how leaders influenced active learning reform efforts in P2C2 courses at Phased Change University and Long-Term University. Throughout this section, we present evidence of how coordination efforts at both institutions have grown in tandem with efforts to support active learning in P2C2 courses. As one department leader from Long-Term University replied, when asked about the role of coordination in supporting changes, "These things wouldn't work without coordination." At both universities, coordination was a vehicle for implementing and sustaining active learning. As mentioned previously, we use Kezar and Gehrke's (2015) framework to identify actions taken to initiate and implement reforms during the potential and coalescing stages and how reforms were sustained during the maturing and stewardship stages. Following each section, we discuss explicit connections to the four frames and describe the major outcomes of the stages. Table 5 presents an overview of the structure of our results and discussion.

Table 5 Summary of results and discussion

Stages of transformation (Kezar and Gehrke 2015)	Primary results	Discussion using the four frames
Potential and coalescing stages of reform	Stimulus for change Leadership during the initiation Major outcomes: The reforms	At both institutions, there were *people* whose values (*symbols*) aligned with visions for change who had the *power* to initiate changes. Moreover, it was important for those *people* to create *structures* in order for these changes to move through to the next stage of reform
Maturing and stewardship stages of reform	Distributing leadership Expanding and institutionalizing Facing challenges	As efforts expanded, leaders needed to involve other *people* who shared similar values (*symbols*) into reform efforts, which allowed the *structures* to become institutionalized. When challenges arose, the leaders (*people*), *structures,* and shared values (*symbols*) had enough *power* to sustain the changes

The potential and coalescing stages of the reforms

The potential and coalescing stages from Kezar and Gerhke (2015) relate to the initiation and implementation of the reforms from these two sites. Because it was difficult to distinguish between these two stages in our analysis, we discuss them together and highlight two major points of comparison: the stimulus for change in each department and the leadership involved in the early stages of the reforms.

Stimulus for change

Both mathematics departments began changing their P2C2 courses by incorporating active learning in Calculus 1 and increasing course coordination. At both universities, prior to these reforms, P2C2 courses were taught via lecture, some with recitations in which instructors demonstrated homework solutions. After the reforms, both departments set a goal that at least half of the course time would be spent engaged in active learning; Phased Change University also set aside one class period per week as time for collaborative group work on projects. Reforms at Phased Change University began after two department leaders, the department chair and the chair of undergraduate education, decided to change the structure of Calculus 1 recitations.

At the time, the chair of undergraduate education, who was also overseeing Calculus 1, discovered that recitation sections were not being used in a productive way. As he recounted, "the recitations were question and answer periods where it would be five or six or seven of the students in the class would show up and they would ask 20 min of questions and it was dismissed." He viewed this "wasted" recitation

time as especially problematic given that Calculus 1 is an integral course for many students at Phased Change University.

To address the situation, the undergraduate chair and department chair decided "to make the recitation a more conceptual experience to the students" by transforming it into a session with active learning where students would work together on common projects. Both leaders had prior experience developing and implementing class projects in a course for pre-service teachers, which motivated them to create similar conceptual worksheets for Calculus 1.

Unlike the mathematics department at Phased Change University, the mathematics department at Long-Term University received top-down pressure to "fix" Calculus 1 due to student complaints and low pass rates. As one faculty member said, "Calculus was the most complained about class by a huge margin." A member of the Board of Regents heard about these complaints and called the department chair to express his displeasure. As one faculty member recalled, after that conversation, "the power structure of the entire university aligned toward fixing calculus."

Although the motivation behind improving Calculus 1 was partly external, reforms were initiated because the department was willing to change; one campus administrator noted that other departments at Long-Term University had been similarly pressured without comparable positive results. Around this time, the NSF had put out a call to fund "reform projects" that focused on changing the instruction of calculus for better student outcomes and student retention. Thus, three faculty members submitted and received an NSF grant to incorporate the use of technology (primarily graphing calculators) and a reform-oriented calculus textbook (i.e., Hughes-Hallett 1994) into their Calculus 1 course. The purpose of these changes was to help students develop a conceptual understanding of calculus in addition to developing mechanical skills and procedural fluency. The grant also allowed Long-Term University to renovate their classrooms in order to support cooperative learning. One of the original leaders of the reform stated that without this NSF funding, their initial reforms would not have succeeded.

Leadership during the initial stages of the reforms

Reform efforts at Phased Change University were led by two leaders who held critical roles at the time of these changes. The faculty member overseeing Calculus 1 felt like he was able to initiate these changes because he "had power to order them [the other calculus instructors] to do stuff." Although he and the department chair were fully committed to carrying out these reform efforts, they were concerned about getting other mathematics faculty to support their efforts. Another faculty member who later joined the leadership team reflected on the departmental culture at the time of initial reforms:

> In this department, if they [the two leaders] had to go through the process of saying, "This is a good idea. Let's do it. Let's educate our faculty about what it's going to take and get support and buy-in before voting on it," it would have never happened. On the other hand, they did it under the radar.

The department leaders also took advantage of the fact that faculty members at Phased Change University rarely teach Calculus 1, so many faculty members were largely unaware of the initial changes being made to the course. Thus, by flying "under the radar," these department leaders were able to establish reform structures that were difficult to undo.

Despite downplaying reform efforts within their own department, the leaders in the mathematics department at Phased Change University leveraged their connections to administrators and other department leaders on campus who had successfully implemented similar educational reforms to support their change efforts. The leaders in the mathematics department at Phased Change University had a particularly positive relationship with their dean. She supported the leaders' initial reform efforts not only because Calculus 1 was an important "gateway" course, but also because the leaders were "truly dedicated to improvement." As one mathematics faculty member stated, this administrator "in essence made the resources available to us for everything we've done in the last four years." In addition to garnering support from administrative leaders, reform leaders in the mathematics department reached out to other departments on campus to learn about their successful reform efforts, which ultimately influenced reforms in Calculus 1.

Although the mathematics department at Phased Change University benefitted from the reform efforts of other departments, the mathematics department at Long-Term University was a pioneer in educational innovation on their campus at the time. Other departments at Long-Term University had not undertaken similar reforms, so the mathematics department had to develop their own vision for these changes. After early pilots in Calculus 1, reform leaders in the mathematics department became "vigilant" in attending workshops on effective implementation with technology and active learning. These leaders were described as "evangelists," people who were able to articulate and defend positive outcomes of this type of model for teaching. When local funding for higher education declined, these "evangelists" were able to help "sway" the department and college to keep reform changes in place. Thus, early leaders were able to advocate for the importance of sustaining these reforms.

Another key difference between reforms at the two universities was the role of the department chair in initial reforms: the chair at Phased Change University was directly involved in initiating changes, whereas the department chair at Long-Term University played a more supportive role. The chair at Long-Term University did not have a direct hand in writing the NSF grant; however, he strongly supported the faculty members who were leading the reform efforts. Like reforms at Phased Change University, change efforts at Long-Term University also benefited from the fact that most senior faculty were largely uninvolved with P2C2 courses. As one of the initial reform leaders stated, "it would have been different if you had someone who was really involved with Calculus and education issues and didn't like it." Because the faculty involved were "of one position"—in favor of the reforms—they were able to initiate and implement lasting changes.

Major outcomes of the potential and coalescing stages: the reforms

Along with introducing active learning projects in Calculus 1 recitations, leaders at Phased Change University decided to create a mathematics learning center for students to go for homework help, as recitations were no longer devoted solely to this purpose. With support from their dean, they also created a full-time coordinator position to oversee Calculus 1 and 2. This coordinator became instrumental to reform efforts. Her contributions to the department included developing additional active learning resources to be used in both recitations and during the regular course meetings, revising the graduate student professional development course to include active learning pedagogies, and facilitating discussions about active learning in course coordination meetings.

In addition to creating a coordinator position, reform leaders in the mathematics department at Phased Change University drew on the established learning assistant models of other departments on campus to create their own Learning Assistant program. The mathematics department incorporated learning assistants in Calculus 1 and 2 to support their recitation sections. Beyond these additions, leaders at Phased Change University did not make significant changes to the actual structure of Calculus 1 (e.g., extending class time, increasing enrollment capacity, changing typical course instructors). Instead, they focused on creating new active learning materials and providing professional development opportunities for graduate students and learning assistants.

At Long-Term University, reform leaders also prioritized the coordination of P2C2 courses by creating a coordinator position, instituting course meetings, developing lesson plans for the first few weeks of class, and standardizing assessments. They also designed a weeklong pre-semester teaching workshop for beginning instructors with sessions focused on using active learning techniques. Over time, the coordinator position has evolved, and more coordinators have been hired to manage the numerous P2C2 sections.

Moreover, initial reforms at Long-Term University involved significant structural changes to support active learning in Calculus 1. These changes included extending class times to 80 min, capping course enrollments for each section at 35 students, and redesigning classrooms to have more whiteboard space and movable tables and chairs. These structural changes have since been expanded to other P2C2 courses.

Table 6 provides a brief comparison of the impetus for change, the leaders of the initial reform efforts, and the resulting changes at each university.

Using the four frames to understand the potential and coalescing stages of the reforms

The contexts for the initial implementation of reforms were different at the two universities. Although reforms at Phased Change University and Long-Term University started for different reasons, both departments chose to focus early

Table 6 Summary of reforms

Phased change University	Long-term University
Why did changes start? Department leaders wanted to change Calculus 1 recitations from a question–answer session to a more meaningful format	*Why did changes start?* Student complaints about Calculus 1 reached upper administrators who then pressured the mathematics department to make changes
Who led the changes? The mathematics department chair and the chair of undergraduate education initiated change efforts; additional faculty joined over time	*Who led the changes?* Three faculty members initiated change efforts; additional faculty joined over time
What were the major changes?	*What were the major changes?*
Developed active learning recitation projects and manipulatives for supporting the projects	Selected and developed course materials designed to facilitate cooperative learning (e.g., group homework)
Created a mathematics learning center	Developed professional development workshop for graduate student instructors and postdocs to encourage the use of active learning strategies
Hired coordinator to oversee the coordination of Calculus 1 and 2	Hired coordinators to oversee coordination of P2C2 courses
Revised graduate student professional development course to include support for using active learning strategies	Redesigned classrooms to support active learning
Introduced learning assistants into recitations	
Infused active learning into the regular course meetings	

efforts on establishing new instructional materials (*structures*) that encouraged student collaboration and conceptual understanding.

However, merely providing curricular materials to faculty is often not enough to encourage lasting change (Henderson et al., 2011). Viewing these efforts from the *people* and *power* frames makes it evident that these structural changes were successful because they were headed by an intensely committed group of faculty (*people*) who were either formal leaders in their department or had the support of formal leaders (*power*) to make such changes. These reform leaders formed *structures* that embodied their personal values and vision for instruction (*people/symbols*).

At Long-Term University, the mathematics department was one of the first departments on campus to incorporate active learning. Therefore, their commitment to using active learning strategies (*symbols*) was not yet widely shared with other departments. In contrast, Phased Change University's mathematics department benefitted from other departments' prior efforts to improve education (*structures*) and shared values (*symbols*). Thus, it is possible that the reform leaders (*people)* at Long-Term University had to utilize their *power* differently from Phased Change University in order to implement reforms. Nevertheless, leaders in both mathematics departments exhibited strong commitments to educational innovation; such commitment is embodied in the *symbolic* dimensions of culture: the beliefs and values of those involved. This commitment translates into support for *people* and *structures* that perpetuate and refine reform strategies.

The maturing and stewardship phases of the reforms

The maturing and stewardship phases relate to how each mathematics department sustained the changes that were enacted. From our analysis, we found three major themes that relate to the maturing and stewardship phases: first, how the departments were able to distribute leadership among a team of people; second, how they expanded their change efforts within the department; and third, how departments responded to challenges. We discuss how each of these themes connect to the sustainability of changes within each department.

Distributing leadership

At both universities, initial reform efforts were primarily led by formal department leaders or full-time professors with informal leadership roles. Over time, new faculty moved into formal leadership roles in the mathematics department at Phased Change University. These new leaders in formal positions maintained the department's overall commitment to supporting active learning reform efforts.

In 2010, the mathematics department at Phased Change University appointed a new department chair who was supportive of the initial changes that had taken place in Calculus 1. However, as she noted, "in Calculus, it was becoming hard to get faculty to play the role of 'czars' so to speak—leader, course coordinator—because it was very time consuming and we didn't actually have a way of [giving faculty] a course release for it." During this time, the new chair for undergraduate education had started "advocating" for the department to hire a dedicated instructor to coordinate Calculus. With the support of the department chair, the undergraduate chair wrote a proposal to hire a full-time coordinator for Calculus 1 and 2, which was subsequently approved by administrators. As the undergraduate chair recalled, "the main impetus for hiring her [the coordinator] was just to get consistency in that job and get someone who was really invested in that job and have it done well."

After hiring a coordinator, department leaders gave her free rein to structure and oversee the coordination system. She became a key leader in future directions of reform efforts, going above and beyond what was originally envisioned for the position. As one senior faculty member said, "[She] came in and made the project her own. She has brought an attention to detail and such a desire to improve things that she ended up doing the job of several people."

At the same time that the coordinator at Phased Change University started her position, a new department chair was appointed. This department chair recognized that coordinating both Calculus 1 and Calculus 2 was too demanding for one person. To sustain reform efforts, he strategized how to build relationships and structures "that would survive any one person being in charge of them," and more coordinators were eventually hired to support the P2C2 sequence. A few of these coordinators were hired explicitly because they value active learning. Now each P2C2 course has its own coordinator, thus distributing the leadership around active learning and P2C2 coordination even further.

Similar to Phased Change University, departmental support from formal leaders at Long-Term University "has been unwavering." One of the original leaders of the

reform efforts became department chair. In order to "keep everything in place" and "protect" the changes that had been made, he leveraged his role to hire a dedicated coordinator. He wanted to hire someone who could "continue to carry the work forward." Originally, one person was hired as a director to oversee the entire coordination system, where faculty served as individual course coordinators on a rotating basis. Like at Phased Change University, this director was critical in structuring and improving upon the existing coordination system. Eventually the department was able to hire multiple semi-permanent instructors to serve as course coordinators for the P2C2 courses. When asked about this change, one coordinator reflected that, "before we were here, there was only one person that was constant. There was one director, and all the coordinators rotated. There was no official team." Furthermore, as another coordinator said,

> Those courses that had rotating coordinators were sort of more variable than they are now…it used to be that whoever was coordinating the course would just decide how things got dealt with. They might consult the director of the program, but they might not.

Before retiring in 2012, the original director mentored the new group of coordinators to support them in their roles. The coordinators now work as a team to oversee the coordination system, regularly communicating with one another and rotating the courses that they coordinate so they are able to share their institutional knowledge. Having this network of coordinators distributes leadership responsibilities, making the role more manageable and ensuring that one person is not solely responsible for maintaining the coordination structure. Hence, this distributed leadership model has resulted in a "self-sustaining" coordination system at Long-Term University.

Expanding and institutionalizing the reforms

Over time, the use of active learning at both Phased Change University and Long-Term University expanded to other courses and became integrated into everyday teaching practice. Reforms at both universities began in Calculus 1, expanded to Calculus 2, and then expanded to other multi-section courses. After incorporating active learning projects into Calculus 1 recitations at Phased Change University, leaders in the mathematics department received an external grant to develop additional active learning materials to be used in regular class sessions. Similar changes followed in Calculus 2. These changes "made a huge difference in the administration's understanding of" the reform efforts in the mathematics department and proved that the changes were "continually worth investing in." At the time of data collection, the mathematics undergraduate committee at Phased Change University was currently working on making similar changes to Precalculus and Calculus 3. One interviewee mentioned that these changes were motivated partly by students who expressed a desire for Calculus 3 to have the same structure as their Calculus 1 and 2 courses. Furthermore, as one faculty member stated, "it's kind of a big deal that the undergraduate committee department has decided to extend this to Calculus 3 because (a) that's not under the radar, and (b) that's more people picking up the

mantle." Recall that leaders at Phased Change University attributed their successful launch of reforms to the fact that most faculty were unaware of these efforts.

The undergraduate committee's explicit involvement in expanding reforms indicates a huge shift in the department's awareness and endorsement of the reforms. The expansion and institutionalization of active learning in P2C2 courses at Long-Term University followed a similar trajectory as reforms at Phased Change University. A few advanced mathematics courses at Long-Term University were already taught using inquiry-based learning, which perhaps allowed active learning strategies to infuse into other multi-section courses more quickly than at Phased Change University.

At both universities, coordinators have played a pivotal role in not only ensuring the success of expansion efforts, but also building a departmental culture that values active learning practices. The coordinator at Phased Change University played an essential role in coordinating and designing the use of active learning materials for both Calculus 1 and Calculus 2. In addition, this coordinator took on the responsibility of leading the graduate teaching assistant professional development course. This seminar course had been put into place in the early 1990s, but after the coordinator was hired, she made significant changes to the course structure. As one senior faculty member stated, she "made it pedagogically sound" and "took it from a weekly meeting to a real course that led to the development of our TAs [teaching assistants] and brought them along to active learning." Although it was not a smooth transition, the coordinator was eventually able to convince the majority of graduate teaching assistants to support the use of active learning in Calculus 1 and 2, thus creating an "army of people" who were interested in developing and using active learning materials.

This transition cemented many of the changes at Phased Change University and provided a critical mass of people who were supportive of the reform efforts, a necessary component of sustaining educational innovations.

The coordinator at Phased Change University also helped educate faculty members about active learning by securing funding for an inquiry-based learning (IBL) workshop. This workshop was well attended by many members of the mathematics department and increased faculty awareness of active learning. According to a department leader, this workshop showed that "there's interest among people in what this is all about and what's going on, and it's gotten people's attention in the department." Similar to Phased Change University, course coordinators at Long-Term University have also taken on the responsibility of leading professional development for P2C2 instructors. The primary form of professional development at Long-Term University is a weeklong teaching workshop for P2C2 instructors that is organized and run by the course coordinators. During this workshop, coordinators emphasize the benefits of active learning for students, and several of the sessions are focused on helping novice instructors implement active learning practices.

Facing challenges

Kezar and Gehrke (2015) identify several potential challenges that communities of transformation face during their development, many of which were reflected

in the reform process at Phased Change University and Long-Term University. In an effort to implement and sustain the reforms, the mathematics departments at Phased Change University and Long-Term University have had to deal with issues regarding resource allocation, leadership turnover, incentivizing reform efforts, and counteracting the dominant culture of mathematics education. In this section, we address how leaders in each mathematics department have dealt with these challenges and how these challenges might impact the sustainability of reform efforts.

Resource allocation Both mathematics departments at Long-Term University and Phased Change University faced challenges related to funding at various points in their development. At Long-Term University, the resources needed to sustain coordination and the use of active learning strategies seem to be permanent. Much of the work to acquire these resources was done at the onset of reforms, although to maintain and expand efforts, leaders have had to strongly advocate for their program. For example, the department faced challenges when they first decided to hire a director of the coordination system. The faculty member who served as department chair at the time recalls having to "battle" the university in order to hire the director, since, at the time, the university preferred not to hire instructors. Furthermore, according to a faculty member at Long-Term University, in the mid-2000s, university administrators were "pushing very hard to increase class sizes." Department leaders responded by collecting data on the impact of the reforms and using these data to demonstrate the effectiveness of reforms to administrators. Now, department leaders at Long-Term University benefit from a college culture and college administration that prides itself on its commitment to excellent teaching, making it less of a battle to receive necessary resources. In recent years, a previous provost, who was also a mathematician, demonstrated his support of the coordination system by teaching a coordinated Calculus course and actively participating in coordination structures (e.g., common grading, weekly coordination meetings). In contrast, faculty members at Phased Change University described having to continually "fight for the smallest things" to sustain and expand ongoing changes. Department leaders have responded to this challenge by using data on student success in P2C2 courses to convince upper administrators of the importance of preserving existing resources.

Leadership turnover Nearly all leaders in formal positions at both universities have changed since reforms began. Throughout the leadership turnover, critical aspects of the reforms have been sustained and expanded because core reformers and outgoing leaders actively worked to ensure the sustainability of efforts with new leaders. One Long-Term University faculty member stated that "the sustainability [of reforms] is just because we've had constant support from the department. Every single chair, at least since I've been here, has been awesome about supporting the calculus program. And we've had very good support, typically, from deans and provosts." Even though Phased Change University's reforms are more recent as compared to Long-Term University, they also have experienced significant lead-

ership turnover. One of the original two faculty members who initiated changes, who was the department chair during that time period, left the department after a few years. Fortunately, the new department chair was committed to supporting the reform efforts and helped sustain the initial changes. When interviewing one of the original leaders, he had this to say about the new department chair: "somehow, she sustained what was happening for the years while she was chair and I don't know how she did it." As mentioned above, she was also critical in hiring the first full-time coordinator at Phased Change University. The next department chair was not only supportive of the change efforts, but he also became part of the leadership team. At the time of data collection, even though they have successfully navigated some leadership turnover, faculty members at Phased Change University expressed some concern about what could happen when new leaders who may be unfamiliar with the reforms take over. As one coordinator stated, "I worry a lot about our future, you know, [one original reform leader] is so key to what's happened over decades….he's just been the sustainer of it. You know? And he'll retire at some point." Furthermore, at the time the department was being led by an interim chair from another department in the college.

Incentivizing reform efforts Another challenge in sustaining reform is creating a culture that supports and rewards leaders in educational innovation. At both institutions, leaders in formal positions were able to incentivize reform efforts by creating explicit structures that supported the work of coordinators. In the early stages of strengthening coordination at Phased Change University, "the chairs individually took it upon themselves to give faculty some course relief to devote the time to developing these active learning models." The department continues to provide course releases for faculty who are engaged in course restructuring efforts. It is important to note that some upper administrators may not be in favor of providing course releases, further highlighting how committed department chairs have been to reform efforts. At Long-Term University, the coordinator role is a more well-defined position. Coordinators receive course releases for their work. Furthermore, the department is willing to hire co-coordinators if the number of sections exceeds a certain amount per coordinator. Coordinators at Long-Term University are also eligible for promotion based on teaching excellence. In contrast, the promotion process at Phased Change University for coordinators, who are instructors, is based on years of experience rather than merit. Consequently, the coordinators at Long-Term University have stayed in their roles longer, providing continuity and institutional memory, whereas coordinators at Phased Change University mentioned feeling like "second-class citizens" at times, yet have maintained enthusiasm for the departmental mission.

Counteracting the dominant culture of mathematics education Given that, historically, undergraduate mathematics instruction has been dominated by lecture-based instructional practice, it is unsurprising that efforts to normalize the use of active learning strategies were met with resistance from instructors at both universities. Both universities largely focused their efforts on reforming the instructional

practice of graduate student instructors—and in the case of Long-Term University, postdocs—with the hope that their status as nonpermanent and (typically) novice faculty would make them more amenable to using innovative instructional practices than permanent faculty. Despite this assumption, both departments experienced pushback from instructors at the beginning of their reform process.

At Phased Change University, this pushback was most noticeable when leaders in the mathematics department extended active learning in Calculus 1 from one day a week to all class periods. This action provoked resistance from a significant portion of graduate students, prompting the calculus coordinator to revamp the department's pedagogy course to include more discussions about effective instructional practice. The coordinator used the seminar course as a way of communicating the benefits of active learning for students, as well as training graduate student instructors on how to use active learning strategies effectively. Over time, the majority of these previously skeptical graduate students began to understand how using active learning strategies could enhance student learning.

The mathematics department at Long-Term University uses instructor development for a similar purpose: to help P2C2 instructors appreciate the benefits of using active learning strategies. Numerous instructors described the pre-semester orientation as critical in establishing the norms of the department. One faculty member at Long-Term University conjectures that pushback from instructors, although inevitable given the scale of their program, is minimal at this point due to the longevity and duration of reforms. As one coordinator from Long-Term University described "this is the way it's done, which is very different than if somebody was trying to institute it and change how it is being done in the past." We conjecture that a similar phenomenon happened at Phased Change University, helped by the fact that graduate student instructors who were not bought into the reforms—even after participating in the pedagogy course—have since graduated from the program.

Using the four frames to understand the maturing and stewardship stages of the reforms

Although attending to the four frames in the beginning stages of reform is important, it is also necessary to continue attending to people, power, structures, and symbols as reforms move beyond the initial changes into the maturing and stewardship stages. Below we discuss how the reforms attended to the four frames with respect to the leadership, expansion of reforms, and challenges that each department faced in sustaining their efforts.

Connecting the four frames to distributed leadership

Whereas leadership is clearly about people, the related *power*, *structures*, and *symbols* are also inherent to effective leadership. The *structures* and power dynamics in departments, as well as the individuals with formal and informal leadership roles, all contribute to positioning leaders to initiate, implement, and sustain educational

reforms. Reform leaders in both departments had a mixture of formal and informal leadership positions; each of them had sufficient *power* to lead these efforts. In some cases, the structure of formal leadership lent *power* to leaders (such as the coordinator role at Phased Change University), and in others, specific faculty's long-standing position in the department lent *power* to their informal leadership (such as faculty at both universities involved in the initial change efforts).

Leaders at both institutions drew on *power*, *people*, *symbols,* and *structures* to use their leadership to sustain change efforts. To sustain active learning reforms, leaders worked to make their personal commitment to active learning a shared value (*symbols*) among others in the department. Part of this process involved distributing *power* to others in the department, thus giving them a sense of ownership in the reform process. This distribution of leadership has been a way that leaders have helped converge top-down and bottom-up approaches, but sustainability means ongoing efforts to balance top-down and bottom-up convergences, particularly through leadership turnover. At both Phased Change University and Long-Term University, leaders gave coordinators the *power* to improve and expand coordination structures. Continuing improvements to the *structure* of coordination systems helped make these structures more robust, thus contributing to the institutionalization of active learning. In addition, coordinators at both universities were responsible for the professional development of new instructors. They used this *power* role to shift individual instructors' beliefs about active learning, which in turn helped shift instructional norms (*symbols*) within the larger department.

Expanding and institutionalizing reforms within the four frames

One overly simplistic view of these expansions would be that both Phased Change University and Long-Term University copied and pasted *structures* (e.g., projects) from one class to another. And to those on the outside looking in, seeing these *structures* would be the most obvious, physical sign of expansion. But, with the help of the four frames, we can see much more deeply the significance of how *people* utilized *power* to continue to grow the *symbols* already embedded in Calculus 1. Beyond departmental and institutional norms, reform leaders *(people)* in both mathematics departments also needed to address discipline-wide cultural norms that have historically valued instructional autonomy and lecture-based instructional practices (*symbols*).

At Phased Change University, leaders recognized that in order to successfully expand active learning reforms, instructors (*people*) first needed to be convinced of the benefits of active learning for student success (*symbols*). The role of the coordinator (*people*) was pivotal in making active learning materials and experiences (*symbols*) stronger and impactful, helping convince and support the instructors and other faculty (*people*). At Phased Change University, students (*people*) voiced their desire for the next Calculus class to be like the previous one they had taken, which exemplifies not only how students used their *power* but also how leaders were able to leverage that *power* in order to expand active learning reforms. Thus, leaders were able to shift the culture of the mathematics department toward active learning by attending to a multitude of aspects of *people, power,* and *symbols.* This allowed the

right *people*, who embodied the vision (*symbols*) and had *power,* to help artfully extend the *structures* from one class to another, which was a key step in sustaining these reforms.

Uncovering the four frames within facing challenges

To sustain cultural change, leaders must attend to all four frames. Challenges to sustainability arise when one or more of these frames is overlooked. At both universities, initial reforms efforts were supported by external grants, but sustaining changes necessitated more permanent resources. To advocate for these resources, leaders needed to consider the values of upper administrators (*symbols*), who were in control of distributing such resources (*power*), and align the outcomes of change efforts with those values. For example, when upper administration at Long-Term University threatened to increase class sizes, leaders collected and used data to show upper administrators that this change would be detrimental to student success in P2C2 courses. By attending to the *symbols* and *power* of upper administrators, leaders at Long-Term University were able to sustain small class sizes, thus thwarting a top-down decision that could have caused severe misalignment. It is likely that these efforts would have failed if leaders did not recognize the importance of attending to outcomes that upper administrators valued. To respond to leadership turnover, reform leaders continually advocated for resources by considering the values (*symbols*) of those in *power*.

At each of the universities, leaders (*people*) have been instrumental in sustaining reforms. Despite leadership turnover, both departments were able to cultivate shared values (*symbols*) around the importance of active learning. In addition, those in positions of *power* worked to hire new P2C2 instructors and coordinators (*people*) who were committed to the departmental vision. At Phased Change University, the decision to hire a full-time coordinator was key to sustaining and expanding reform changes in Calculus 1 and 2. This coordinator quickly became a leader of reform efforts and helped graduate students and faculty members at Phased Change University understand the value of using active learning in P2C2 courses (*symbols*).

Although leaders at Phased Change University have worked to change departmental values, they still face significant challenges due to a lack of incentive *structures* for those engaged in the reforms. Specifically, instructors (*people*) described feeling like "second-class citizens," expressing a lack of *power*, despite the department's belief that they are valuable. This conflict in values (*symbols*) has the potential to undermine reform efforts, posing a considerable risk to the sustainability of the reforms. Overlooking *people* in this way could lead to the turnover of important reform leaders. Although this turnover had not yet happened at the time of data collection, this imbalance between the four frames threatens the stability of P2C2 reforms and presents leaders at Phased Change University with a serious challenge, particularly from top-down decisions that are not in alignment with their vision and process. In contrast, Long-Term University has created *structures* to help their instructors (*people*) feel more valued. For example, coordinators have a well-defined position (*power*) in overseeing reform efforts and benefit from having a path to promotion (*structure*) based in part on their contributions to these efforts.

A major challenge that leaders in both departments faced was getting P2C2 instructors to develop a shared understanding of the value of active learning (*symbols*). At Phased Change University, leaders worked to expand active learning *structures* in the lecture portion of Calculus 1 classes. However, this expansion was ill-received by the graduate students (*people*) teaching these lecture sections, who did not share the same set of values (*symbols*). To address this, the calculus coordinator incorporated professional development centered on active learning into the graduate student pedagogy course. Gradually, this structural change resulted in a shift in values (*symbols*) among Calculus instructors. Thus, by attending to the *symbols* of the instructors (*people*), the calculus coordinator was able to sustain changes to the Calculus 1 course at Phased Change University.

Conclusions

We recognize that these efforts occurred within two particular local contexts that are not representative of all institutes of higher education. However, the efforts of reform leaders in these two departments can still inform leaders in other departments considering similar changes. For example, at both institutions, leaders started reforms within classes that are taught by those who, arguably, have less power in the department than full-time professors: graduate students, postdocs, and other instructors. However, support from these instructors was far from guaranteed; leaders had to work to gain instructors' trust and stimulate their interest in using active learning. We contend that the lessons learned from these leaders' actions can still inform change efforts in different contexts.

The departmental changes at both universities are substantive and have been sustained through changes to leaders and instructors. The changes can be viewed through Reinholz and Apkarian's (2018) four frames: *people*, *power*, *symbols* and *structures*. When department leaders initiated changes, they acted as "system thinkers" (Fullan 2006) who attended to the multiple cultural dimensions in which the P2C2 program was placed when considering the changes they needed to make. Applying the four frames gives us a way to reframe the change process from a cultural perspective, allowing us to better understand how department leaders initiated, implemented, and sustained cultural changes within their mathematics departments in ways that support active learning.

Taking a stance that effective leadership is distributed allowed both sites to use a mixture of formal and informal leaders (from both top-down and bottom-up positions) to initiate, implement, and sustain reforms. The leaders at both sites understood they needed to consider not just the people, but also the power dynamics, and that reforms coming solely from "above" may not be sustained as people in those top-down roles change—which are two of several challenges Kezar (2012) says can emerge from the convergence of top-down and bottom-up leadership. Distributed leadership is intentional about positioning people in both formal and informal roles to have the power necessary to enact aspects of the reform process (Spillane and Diamond 2007). Both sites for this study involved balanced partnerships of formal and informal leaders who worked well with each other and understood how to enact

department-wide changes. Such balanced partnerships are not necessarily universally present. Other departments seeking to enact similar changes may not have similarly positioned leaders who can effectively combine top-down reforms, backed by the chair, with bottom-up reforms emanating from faculty. In those cases, people seeking changes should consider how to convince well-positioned leaders to support proposed reform efforts.

Although studies of leadership and distributed leadership often approach roles as dichotomous—top-down and bottom-up—the realities in mathematics departments are often far less clearly split. At both of the universities in this study, course coordinators were key to the implementation and sustainability of reform efforts. Yet, should efforts by these coordinators be seen as top-down, bottom-up or something else? Coordinators are typically faculty members who are also teaching sections of the course they are coordinating; within a department structure, coordinators' power is different from that of the chair. Kezar (2012) identifies *translators* as individuals who serve as connections between bottom-up and top-down efforts. At both universities in this study, we believe coordinators were positioned (or positioned themselves) as translators who were able to create a communication channel that typically does not exist between formal leaders and P2C2 instructors. This extra channel provided a pathway within the overall system for the coordinator to better tie together *people*, *power*, *symbols*, and *structures* in order to institutionalize and expand active learning. We argue that a key reason both universities have been able to sustain reforms is through having coordinators willing and positioned to take on a translator role. More research is needed to better understand the roles of coordinators as translators, and how coordinators move within this communication channel in order to sustain reform efforts within their mathematics department context.

Our hope is that leaders trying to enact these changes can use these findings to guide and inform change processes within their departments. Departments seeking to make similar reforms need to broadly consider the complex systems that created the current state of affairs, as well as the interplay among *people*, *structures*, *symbols*, and *power* inherent in these systems. Effective change strategies address all of these dimensions, particularly at the initiation of reform efforts, and careful consideration of sustainability from the start can help ensure the long-term success of reform efforts. It is tempting for leaders to focus their attention on setting up structures in order to enact reforms; however, the success of these structures ultimately depends on the people interacting with the structures and their associated values. It is not enough to just hire a coordinator or make some projects. When institutionalizing reforms, leaders (*people*) must focus on creating lasting *structures* that embody their values (*symbols*) and empower others to support those *structures*. In order to create these structures, leaders need authority or status (*power*) within the department. Effective translators are a key component to sustaining reform efforts within a distributed leadership framework. Although this work is difficult, the departments described in this manuscript provide proof of concept that this is indeed possible.

Although we described several challenges that these institutions faced when sustaining their reforms, more research is needed to understand how leaders at different types of institutions are able to successfully enact changes, and how such changes may be different in different disciplinary contexts. Moreover, careful consideration

needs to be made when considering different contexts. For example, leaders may face different challenges when reforming P2C2 courses taught by full-time professors who are likely to have more established instructional values and more power to resist changes. Leaders can still draw lessons from these examples, but they may need to leverage one or more of the four frames in different ways in order to shift their colleagues' instructional practice to include active learning pedagogies. Wide-scale changes are needed to better align instructional practices and departmental cultures with what the field knows about effective mathematics teaching and learning. Phased Change and Long-Term Universities provide evidence that this difficult work is indeed possible, and that such changes can be successfully sustained.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article Competing interests.

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Authors and Affiliations

Rachel Funk[1] · Karina Uhing[2] · Molly Williams[3] · Wendy M. Smith[4]

Rachel Funk
rachel.funk@huskers.unl.edu

Karina Uhing
kluhing@unomaha.edu

Molly Williams
mwilliams1@murraystate.edu

[1]   Center for Science, Mathematics, and Computer Education, University of Nebraska-Lincoln, Lincoln, NE, USA

[2]   Department of Mathematics, University of Nebraska at Omaha, Omaha, NE, USA

[3]   Department of Mathematics and Statistics, Murray State University, Murray, KY, USA

4   Center for Science, Mathematics, and Computer Education and Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE, USA