



In the Driver's Seat: Course Coordinators as Change Agents for Active Learning in University Precalculus to Calculus 2

Mary Williams¹ · Naneh Apkarian² · Karina Uhing³ ·
Antonio E. Martinez⁴ · Chris Rasmussen⁴ · Wendy M. Smith⁵

Accepted: 21 July 2021 / Published online: 21 August 2021
© The Author(s), under exclusive licence to Springer Nature Switzerland AG 2021

Abstract

Mounting evidence of the effectiveness of active learning strategies has prompted many mathematics departments to start engaging in transformational change efforts. Change, however, especially change in instructional practice, is a challenging endeavor. Some departments are using coordination of multi-section courses as a vehicle to enact changes and have designated or hired course coordinators to oversee efforts to transform instruction via active learning. This study explores the role of coordinators as instructional change agents for active learning using data collected from five university mathematics departments, all of which are successfully sustaining such efforts. We use Shadle et al.'s drivers for change as a framework for examining data from five retrospective case studies of change. Specifically, we investigate how these speculative drivers connect to coordinators' roles as change agents in each story. We argue that coordinators are positioned to leverage three key drivers for change: providing materials and tools, encouraging collaboration and communication, and encouraging (and providing) professional development. Coordinators must also understand the local contexts and culture in order to engage in effective processes for supporting departmental change. To conclude, we discuss implications of this research for departments seeking to transform instruction.

Keywords Course coordinators · Coordination · Departmental change · Active learning

MW, NA, KU are Joint Senior Authors and contributed equally to this work, AEM, CR, WMS contributed equally to this work.

✉ Mary Williams
mwilliams1@murraystate.edu

Extended author information available on the last page of the article

Introduction

Students in undergraduate mathematics courses are more successful and more likely to persist in STEM majors when they are active participants in their learning rather than passive recipients of didactic lectures (Freeman et al., 2014; Theobald et al., 2020). The evidence for this claim, in general, continues to grow with increasing international calls for greater use of instructional approaches that actively engage students in challenging mathematics (Rocard et al., 2007) as well as theoretical and empirical studies of inquiry-oriented approaches (e.g., Maass et al., 2013). Although the umbrella term “active learning” includes many strategies that may have differential impacts (e.g., Khatri et al., 2017), not all implementations of active learning are equal (Andrews et al., 2011; Stains & Vickrey, 2017). Many mathematics departments have tried to adopt these strategies with different levels of success or are wanting to make changes but are unsure of how to begin this process.

In the United States, there are many efforts to change teaching norms in university mathematics departments. These efforts include those targeted at individuals through the mechanism of professional development (PD) (e.g., Project NExT¹, AIBL²), recommendations for program changes from researchers (Rasmussen et al., 2014) and professional organizations (Saxe & Braddy, 2015), curriculum development (e.g., Boelkins, 2018; Carlson et al., 2020; Lloyd et al., 2017), and funding incentives². While these efforts have all had some impact, most students in introductory STEM courses (including precalculus and single-variable calculus) experience high levels of instructor-centered lecture (Apkarian et al., 2021; Rasmussen et al., 2019; Seymour & Hunter, 2019; Stains et al., 2018). There is now growing support for program-wide cultural change to shift instructional norms at the departmental level rather than through top-down mandates or one-by-one individual instructor change (Reinholz et al., 2020). While such efforts are supported by research and theory surrounding community culture and change (Kezar, 2014; Reinholz & Apkarian, 2018; Schein 2010), they are challenging to implement and require motivated change agents. These change agents are actors who contribute to initiating and sustaining a change process while considering long- and short-term goals, local needs, and the existing cultural context in which they are operating (Martinez et al., *in press*; Rasmussen et al., 2021; White et al., 2020).

One strategy that can help initiate and sustain changes is course coordination for multi-section courses. Many university mathematics departments already have some level of course coordination for precalculus and/or single-variable calculus courses (Rasmussen et al., 2019), and coordination has been suggested previously as a mechanism through which instructional norms develop, and could therefore be shifted (Rasmussen & Ellis, 2015). Coordination systems are led by course coordinators who are positioned as potential

¹ [^https://www.maa.org/programs-and-communities/professional-development/project-next](https://www.maa.org/programs-and-communities/professional-development/project-next)

² [^http://www.inquirybasedlearning.org](http://www.inquirybasedlearning.org)

² In the US, this includes public funding from the National Science Foundation, such as *Improving Undergraduate STEM Education* (NSF-IUSE), and private funding from groups such as the Gates Foundation or Howard Hughes Medical Institute (e.g., *Driving Change*).

change agents and have both formal and informal influence on instructional practices (Apkarian & Rasmussen, 2020). While course coordination can serve as a lever for instructional change, the specifics of how and why course coordinators can support a shift toward active learning have not yet been documented.

In this report, we first provide a theoretical argument for how course coordinators are well-positioned to “nudge” instructional practices toward active learning. We use the term nudge here in the sense of Thaler and Sunstein (2009) and as adapted by Rasmussen and Ellis (2015) to course coordination. Thaler and Sunstein, scholars in behavioral economics, define nudging as any intervention by a person in a position to influence others’ behavior such that the intervention does not limit their choices or options. Thus, nudging is an indirect mechanism for affecting change. To construct our broader theoretical argument, we use the four frames perspective on departmental culture (Reinholz & Apkarian, 2018) and Shadle et al.’s (2017) drivers for undergraduate instructional change. We follow this theoretical framing with an analysis of the role of course coordinators in implementing active learning at five university mathematics departments. We pose our research questions for the empirical part of the paper after our theoretical discussion. The empirical data illustrate and lend credence to our theoretical argument, illuminating with practical examples how coordinators can and do (in certain circumstances) leverage their roles to support change in instructional practice. In our analyses, we use Shadle et al.’s (2017) drivers as a tool to analyze the data itself, and the four frames (Reinholz & Apkarian, 2018) to interpret these findings as they relate to systemic departmental change. We conclude with future avenues for research and implications for practice: to act as a change agent, a motivated course coordinator must be supported by the department, given the power to enact drivers for change, and not be viewed as solely responsible for instructional practice.

Theoretical Framing and Purpose

To frame this study, we use existing research to define the system within which coordinators operate and explain how coordinated systems and course coordinators can propel cultural change.

Defining the System: Coordinators & Course Coordination

A department can be seen as a system existing within a larger system of the university (e.g., Gaubatz & Ensminger, 2017). These systems are complex, consisting of various interactions both within and outside each system. Since this study focuses on the role of a course coordinator within a department, we first define what we mean by a course coordination system. A course coordination system generally consists of uniform course elements and regular instructor³ interactions around teaching a specified

³ We recognize that the term “instructor” has varying connotations across contexts. In this manuscript we use the term to refer collectively to all involved with course content delivery, regardless of rank or title.

course or courses and is overseen by a person designated as the coordinator. At a minimum, a course coordinator centrally manages common course elements (e.g., syllabi, homework, exams, pacing) and facilitates regular instructor interactions about teaching (e.g., meetings, listservs, message boards) (Rasmussen et al., 2021; Rasmussen & Ellis, 2015). A survey of university precalculus and single-variable calculus courses in the USA suggests that roughly 40% of these courses are monitored by a coordinator who holds the position for multiple years; nearly a quarter have coordinators who serve for a single year or a single term in which they are teaching the target course (Apkarian & Kirin, 2017). While this role can be taken up in a minimal way, coordinators also have the potential to serve as change agents and support communities of instructional practice (Martinez et al., *in press*). By creating course materials that lend themselves to active learning and guiding conversations in course coordination meetings, a coordinator can nudge instructors (and perhaps departments) toward using more student-centered instruction and developing a community of practice that values teaching (Rasmussen et al., 2021; Rasmussen & Ellis, 2015; Thaler & Sunstein, 2009; Wenger, 1998). As researchers, we believe that active learning involves 1) students' deep engagement in mathematical thinking, 2) peer-to-peer interaction, 3) instructors' interest in and use of student thinking, and 4) instructors' attention to equitable and inclusive practices (Laursen & Rasmussen, 2019). In this paper, we use a broad conception of "active learning" that would be recognized by the participants in this study: "Active learning is a broad term that incorporates teaching methods and classroom norms that engage students in sense-making activities" (Smith et al., 2021, p. 147).

Figure 1 helps illustrate interactions among coordinators and other individuals within the course coordination system and also the larger departmental system. Figure 1 shows a snapshot of who and what interactions are involved in the coordination of a course.

The inset box surrounded by a dashed line shows the coordination system, which exists within the department and involves interactions among coordinator(s), the instructors who are teaching coordinated courses, the students taking those courses, and the course content. The coordinator oversees the entire coordination system, works directly with instructors, and usually teaches one or more sections of the course (Rasmussen et al., 2021). The permeable box indicates this coordinated course is only a snapshot in time; across terms and years coordinators, instructors, and students move in and out of being active participants. It also reflects the fact that those within the coordination system interact with those outside the system and those interactions can influence practice within and outside the system. We use "instructors" to refer to all individuals involved in content delivery of coordinated courses, including tenured, tenure-track, and non-tenure-track faculty, as well as adjuncts, lecturers, postdocs, graduate students, teaching assistants, and others.

Figure 1 also highlights the interactions among those who are involved in a coordinated course and those who are not formally involved. For example, instructors within a department often interact with each other regardless of whether they are all involved in a coordinated course or not. A similar statement about students can be made. These interactions among instructors and among students are a way knowledge about the coordinated course can be transferred over time, helping create a sustainable expectation of how teaching and learning occurs in both coordinated and

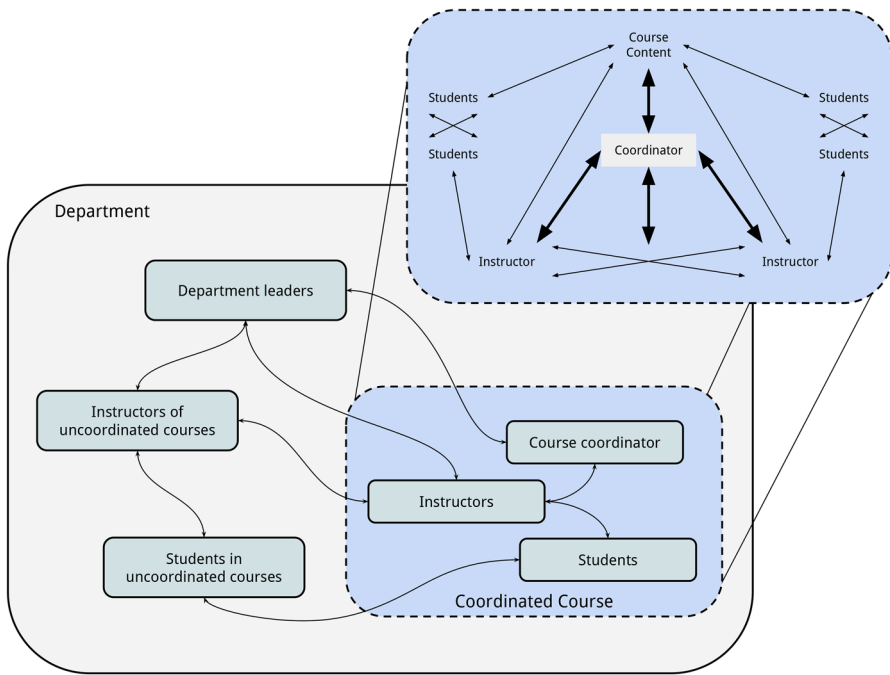


Fig. 1 Diagram of focal interactions, related to instruction, between participants in a coordination system within a department. Here, “instructors” refer to all involved in content delivery

non-coordinated courses. Figure 1 also illustrates the interactions among the coordinator and formal department leaders, such as the department chair or a committee overseeing the course coordination system. These leaders are not consistently involved in the day-to-day operations (Apkarian & Rasmussen, 2020), which is why they are positioned outside of the coordination system. This connection between a coordinator and department leaders assumes a coordinator does not act alone within a department, yet we acknowledge the strength of this connection and with whom the connection exists may vary in different departments. We believe this connection is important because 1) it is a critical way knowledge about the coordination system can be disseminated within the department and also outside of the department to the larger university system (Smith et al., in press) and 2) department leaders can help grant power to the role of the coordinator and support coordinators in their decision-making (King et al., 2015).

Another observation to note about Fig. 1 is the call-out box shows interactions among the course coordinator(s), instructors, and students. The first thing to note is the multiple embedded instructional triangles (Cohen et al., 2003; Lampert, 2001): the inner triangle represents the core work of the coordinator with the instructors and course content, whereas the outside triangles represent how that core work permeates to the coordinated classes with the instructors, students, and course content. In both instructional triangles, the use of multiple arrows among instructors and among students indicates the intention of active engagement: part of the role of a

coordinator is to facilitate and support instructors collaborating with other instructors. Similarly, active learning in coordinated courses involves students engaging with other students. We acknowledge coordinators have the potential to influence the larger departmental system, but in this research, we focus on the role of the coordinator within the coordination system in our results and consider connections to the larger departmental system in our discussion and implications.

Department Cultural Change

Cultural change involves considering, leveraging, and understanding the current culture (starting context), envisioning a desired culture (goal context), and incorporating culture into the design of tactics for moving from the starting point toward the goals. This attention to local context has been highlighted by many as critical for implementing and sustaining meaningful change across a department (Borrego & Henderson, 2014; Henderson et al., 2011; Kezar, 2014; Schein, 2010). One way we can conceptualize cultural change is by using the four frames model (Bolman & Deal, 2008; Reinholz & Apkarian, 2018) as an analytical lens. In the context of STEM departments, Reinholz and Apkarian (2018) used the idea that “culture is a historical and evolving set of structures and symbols and the resulting power relationships between people” (p. 3) as a cornerstone for connecting the four frames to each other and highlighting the importance of carefully defining each of the four frames (see Table 1). According to this theory, departmental culture is ever-evolving yet, “there is some commonality between how individuals interact, and it is important to understand that commonality as well as areas of difference” (Reinholz & Apkarian, 2018, p. 3).

Course coordination systems are connected to all four frames. Therefore, we can view coordination as a vehicle for shifting departmental culture. Coordination systems are *structures*, because they organize the ways in which instructors interact with one another; coordinators and instructors are, of course, *people* and bring their own individual identities, experiences, and goals to their interactions with each other; attitudes and norms, or *symbols*, guide interactions among instructors and coordinators about teaching; and finally, coordination systems have inherent *power* dynamics, most obviously among course coordinators and the instructors. For example, a weekly course coordination meeting is a *structure* that provides opportunities for instructors and coordinators (*people*) to have conversations around teaching practices. During these meetings, underlying assumptions about instructor

Table 1 Description of the four frames as operationalized by Reinholz and Apkarian (2018)

People	Persons with individual goals, agency, needs, and identities who are involved in the interactions
Structures	Roles, responsibilities, practices, routines, and incentives that organize how people interact
Symbols	Cultural artifacts, language, knowledge, myths, values, and vision used to guide reasoning
Power	What is mediating and influencing the interactions (e.g., status, positioning, political coalitions)

autonomy (*symbols*) and the *power* dynamics between different individuals involved in the interaction may influence the direction and outcome of the conversation.

The four frames “speak to the *product* and *processes* of change” (Reinholz & Apkarian, 2018, p. 2); each of the four frames can be used to understand the *what* as well as the *how* of cultural change. Reinholz and Apkarian present some particular examples, yet the four frames can be applied to any aspect of a change initiative and does not prioritize or promote particular strategies over others, nor is it focused on a particular kind of departmental goal. Thus, to focus our work, we bring in additional empirical research concentrated on change levers related to the adoption of active learning strategies in undergraduate STEM departments.

To understand cultural factors related to the adoption of evidence-based instructional strategies, Shadle et al. (2017) designed and enacted department-wide dialogues about changing instructional norms and culture with 12 different STEM departments at Boise State University. Each dialogue began with an introduction to STEM education followed by department members reading through and reacting to a statement of Boise State’s vision for their culture of teaching and learning. During these dialogues, faculty members discussed whether change was happening and the reasoning behind the changes (or lack of changes) in regard to the university’s vision about teaching and learning. Shadle and colleagues’ analysis of these conversations yielded eighteen categories of barriers faculty believed could stop (or were stopping) change within their specific contexts and fifteen categories of drivers that could help (or were helping) overcome barriers and catalyze change. Some of the drivers are related to addressing or removing barriers, others are distinct and go beyond overcoming obstacles. These findings align with research suggesting removing barriers is not the same as supporting change (e.g., Johnson et al., 2018). Neither the drivers nor barriers are ranked in a particular order or organized in any way. Many barriers that emerged are consistent with existing research, such as lack of resources (e.g., Weaver et al., 2016) or resistance to change (e.g., Kezar, 2014). However, less is known about the drivers of change in current STEM education research. Therefore, we focus on the fifteen drivers identified by Shadle and colleagues (see Table 2), which help illustrate how faculty view possible strategies for change.

The drivers shown in Table 2 provide concrete strategies for enacting cultural changes associated with adopting evidence-based teaching practices. Examining these drivers through the four frames lens can provide insight into how and why these drivers might work in a particular context. Each driver presented in Table 2 can be connected to both processes and products of change and one or more of the four frames. As an example, consider the driver “aligns with faculty desires for student success.” As operationalized by Shadle et al. (2017), this driver refers to instructors being “willing to try new things and hav[ing] a shared desire for student success” and the implementation of evidence-based instructional practices being “aligned with current efforts for teaching effectiveness and improved student learning” (p. 6). A “shared desire for student success” is representative of existing cultural symbols in a department, which can “support a proposed change so that it is taken up optimally” (Reinholz & Apkarian, 2018, p. 6). If such attitudes do not exist, they might be a desired product of a change initiative. If such attitudes do exist, the alignment of messaging around the change initiatives is a key part of the

Table 2 Fifteen Drivers for Change Identified by Shadle et al. (2017)

Develops stronger students/graduates	Encourages collaboration and shared objectives	Provides flexibility and encourages exploration
Improves student and department outcomes	Promotes student engagement and faculty-student interactions	Aligns with faculty desires for student success
Encourages professional development	Improved individual and institutional reputation	Enhances teaching satisfaction
Aligns with existing resources	Expands on current practices	Institutional/departmental support
Improves teaching and assessment	Builds common tools and resources	Increased research opportunities

change process. Studying these drivers through the four frames lens can help explain how each driver could contribute to broad cultural changes. In this study, we focus on the role of the coordinator and the drivers that course coordinators are able to directly access and leverage.

Connecting the Drivers to the Coordination System

Each of the drivers presented in Table 2 can be connected to some aspects of a course coordination system that are intended to support or promote active learning, and thus also to the course coordinators managing that system. We argue, however, departmental cultural change should be a shared endeavor, so coordinators should not take on the sole responsibility of exercising all these drivers alone. Yet, we hypothesize the major responsibilities of course coordinators position them particularly well to leverage three drivers to initiate and/or sustain the use of active learning:

1. Building common tools and resources for active learning
2. Fostering collaboration and a shared vision for active learning
3. Promoting professional development (PD) for active learning

We specify “for active learning” when discussing these drivers to emphasize that, while the minimum requirements of a coordinator role might involve building common tools or facilitating PD, engaging these levers *in service of active learning* can spur lasting cultural changes within a coordination system and perhaps beyond. We separate these three drivers for clarity, although in practice they may share many overlapping components.

Building Common Tools & Resources for Active Learning

The first of the three drivers is *building common tools and resources*, a theme which developed out of faculty indicating that “the creation/availability of common tools and resources is a valuable outcome” of initiatives aimed at implementing active

learning strategies in classrooms by making “successful strategies [...] available to all” and providing “a ‘toolbox’ for achieving learning” (Shadle et al., 2017, p. 6). This driver clearly connects to the role of the coordinator in managing, and often developing, common course elements (e.g., shared class activities, common assessments, uniform grading policies, etc.). In practice, these common course elements are often a mixture of required, recommended, and optional materials with policies that function as default options. Setting default options is one method of nudging people toward certain behaviors, in this case toward particular instructional approaches (Rasmussen & Ellis, 2015). When the default options support active learning, active learning can start to become the default—contributing to a shift in culture around instructional practices and norms.

Fostering Collaboration & Shared Vision for Active Learning

The second driver we highlight is *fostering collaboration and a shared vision*. Shadle et al. (2017) expand on this driver, noting that “collaboration and communities of practice is a beneficial outcome of increased emphasis on teaching and student success” (p. 6). This driver is connected to the coordinator’s role in facilitating regular instructor interactions about teaching. Regular conversations about teaching can lead to instructors forming a community of practice focused on instruction with the coordinator in a central membership role (Rasmussen & Ellis, 2015). These interactions often take the form of regular in-person or virtual meetings, but can also include alternative arrangements such as message boards, listservs, and/or collaborative documents (Rasmussen et al., 2021). In addition to providing logistical support and shared materials, coordinators have the ability to help shape the vision of teaching and students within these meetings. Several researchers (e.g., Kezar & Gehrke, 2015) have suggested having a shared vision supports sustainability; when viewed through the people lens of the four frames, it can be linked to ideas of agency and ownership by individuals of a change initiative (Reinholz & Apkarian, 2018). When collaborations and shared objectives come to include active learning and specific implementation strategies, then other frames of departmental culture, such as people and structures, can also begin to shift.

Promoting Professional Development for Active Learning

The third driver focuses on *promoting professional development* and how initiatives related to implementing active learning can be “an opportunity to engage in professional development related to teaching and learning” (Shadle et al., 2017, p. 6). Although some course coordinators are explicitly tasked with PD responsibilities, particularly at universities with graduate student instructors, regular instructor interactions around teaching, as well as the management of course elements, also provide more informal forms of teaching-related PD (Martinez et al., *in press*). When formal and informal aspects of PD focus on supporting active learning, they provide an additional avenue for gathering feedback and nudging instructors to use more active learning strategies. For example, coordinators are often tasked with observing instructors as they teach, giving them an opportunity to provide substantive feedback

to help instructors develop active learning practices; this kind of just-in-time support for student-centered pedagogy is needed to prevent backsliding (King et al., 2015; Speer & Wagner, 2009).

Additional Relevant Drivers

We recognize many drivers listed in Table 2 may also be connected to course coordination systems, but these connections appear more context-dependent and/or accessible to more than just a coordinator. Change agents hoping to shift a department toward active learning should consider all drivers in making their plans - for example, a coordinator might identify current users of active learning strategies and position the coordination system as *expanding on current practices*, thereby connecting the change effort to existing symbols, people, and structures of the department. Our focus is on change levers in service of active learning which are immediately and directly accessible to coordinators and hence we omit further discussion of the other drivers, with two exceptions.

The first of these is *improving teaching and assessment*, which Shadle et al. (2017) described as “expectation for gains in individual teaching ability, confidence, and/or efficiency; more consistent curriculum across sections/department; better assessment processes” (p. 6). The first element of this list is something we, and others, associate with using active learning and PD; the second is an explicit goal of course coordination systems; and the last is a subjective view which might be associated with a coordination system that includes common (or collaboratively developed) assessments. This driver can therefore easily be connected to those we have highlighted, but could also be leveraged through other PD or course redesign efforts. The emphasis of this driver on improving teaching and assessment also brings in cultural symbols about what defines good teaching or assessment practices, which reinforces the idea these drivers should be contextualized within the culture of the target community.

The second additional driver is *providing flexibility and encouraging exploration*, which refers to the idea that “adoption of new teaching practices fosters creativity; exploration/innovation are encouraged” (Shadle et al., 2017, p. 6). We choose not to center this driver as something which all coordinators are positioned to access because it is highly dependent on local context—the extent to which pedagogy is prescribed, the kinds of active learning being promoted, and more. However, this driver is reminiscent of Rasmussen and Ellis’s (2015) construct of coordinated independence, which describes how instructors maintain a level of autonomy within a structured system, as well as Reinholz and Apkarian’s (2018) examples of attending to the people frame in the process and products of change.

Connecting Drivers and Course Coordination Systems

Having discussed three direct drivers, and two more indirect drivers, which course coordinators have clear access to and which can be used to shift instructional practice toward active learning, we consider their relation to the overall system (Fig. 2).

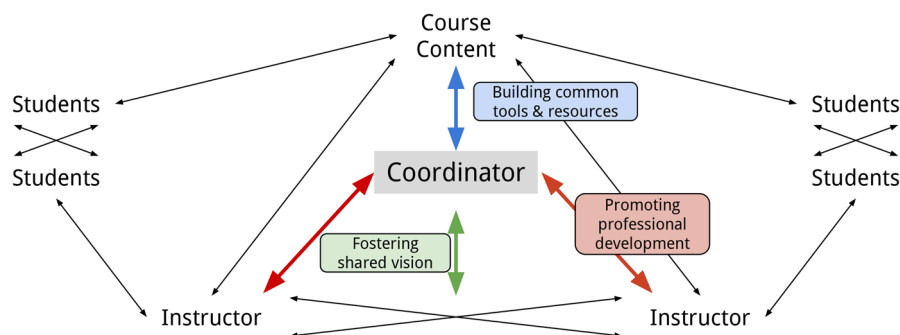


Fig. 2 Diagram of coordinator interactions, annotated with drivers for change

The coordinator has access to the three direct drivers via their work in this embedded instructional triangle of interactions. Each of the three drivers is closely aligned with particular interactions in a coordination system, as indicated by their positions in Fig. 2. That is, building common tools and resources relates to the interactions a coordinator has with the course content; fostering shared vision involves interactions between instructors, some of which are managed by the coordinator; and promoting professional development is most related to interactions between coordinators and instructors more individually. The two indirect drivers we identified are more amorphous and context-dependent, so they are not represented in Fig. 2. The coordinator role can be instrumental in helping departmental and cultural change, but we need to understand more about how the role of the coordinator is positioned to cause this kind of change and what this position allows coordinators to do, particularly related to change associated with active learning. Thus, the research questions that guide the empirical component of this work are:

- *In what ways have course coordinators leveraged their roles to drive the institutionalization of active learning in university Precalculus, Calculus 1, and Calculus 2 courses?*
- *To what extent are they engaging the drivers we identified as complementary to their role?*

Methods and Participants

The data for this qualitative analysis are drawn from a larger study, *Student Engagement in Mathematics through an Institutional Network for Active Learning* (SEMINAL), focused on identifying strategies for successfully implementing and sustaining active learning in Precalculus to Calculus 2 (P2C2) courses. The five universities in this study are all public institutions in the United States with high research activity, and approximate undergraduate student enrollments between 19,000 and 31,000 students. The five sites were chosen because they coordinate their P2C2 courses, although the degree and types of coordination vary by institution, and

have deliberately implemented active learning in one or more of these coordinated courses. We refer to the five institutions using pseudonyms: All-In University (AIU), Long-Term University (LTU), Crossroads University (CU), Phased-Change University (PCU), and Critical Response University (CRU). See Table 3 for a short contextual description of these institutions. Nearly all of the coordinators have (semi) permanent positions (at least three years as a coordinator for each course); a few coordinator positions are held by tenure-track faculty, but most are non-tenure-track, full-time instructors. All of the institutions have multiple coordinators (typically one per P2C2 course). For more information about the larger study, including in-depth descriptions of the university contexts, see Smith et al. (2021). At all institutions, graduate teaching assistants were involved in the instruction of either the main section of the course (instructor of record) or as a recitation leader, which is typical for many coordinated courses in the US (Apkarian & Kirin, 2017).

Data were collected primarily during site visits in Spring 2017 through interviews with key stakeholders (e.g., course instructors, coordinators, department chairs, administrators, students, etc.) and observations of P2C2 courses, totaling to at least 12 interviews (individual and focus group) and three class observations for each site. Audio recordings of the interviews were transcribed and analyzed in qualitative data analysis software MAXQDA (VERBI Software, 2019). The codebook was informed by institutional change literature (including Henderson et al., 2011; Kezar, 2014; Kezar & Gehrke, 2015; Reinholz & Apkarian, 2018; Shadle et al., 2017), the characteristics of successful calculus programs study (Bressoud et al., 2015; Bressoud & Rasmussen, 2015), and the site visits themselves. Each interview was independently coded by at least two researchers, who then met to reconcile their coded segments (Creswell & Poth, 2018). Two rounds of member checking (Creswell & Miller, 2000) occurred: one with an initial report by the site visit team and then later with a longer report from the in-depth analysis with MAXQDA. Each report was sent to representatives of the departments, who were invited to provide feedback. For more information regarding the data collection and analysis, please refer to Smith et al. (2021).

To better understand how coordinators may leverage the drivers identified by Shadle et al. (2017), we first selected interview excerpts that were identified with the “coordination” code. All six authors then analyzed these excerpts for evidence of Shadle et al. drivers, with particular attention to building common tools and resources for active learning, fostering collaboration and a shared vision for active learning, and promoting PD for active learning. This analysis process confirmed these three drivers are the most relevant for understanding the unique role of a course coordinator in supporting instructional change at the departmental level. A keen focus on the coordinator role was kept: if an excerpt was about one of the three drivers but did not relate directly to the coordinator, then it was removed. With this set of excerpts identified as germane to the three drivers for change, we then analyzed the excerpts by individual site, to develop a coherent understanding of how coordinators are positioned to leverage the three drivers for change. With a thorough understanding of how coordinators at each site were utilizing these three drivers for change, all six authors made comparisons across the five sites to look for commonalities and differences. In this reconciling, the authors constructed a list of general themes regarding commonalities and differences. We then generated subthemes

Table 3 Short Description of the Five Sites in this Study

University Pseudonym	All-In University	Crossroads University	Critical Response University	Long Term University	Phased Change University
Undergrad. (approximate)	30,000	20,000	20,000	30,000	30,000
Dept. size	80	130	220	300	120
Description of Pseudonym Origin	Department chair and Task Force created a detailed plan that went “all in” on implementing AL and tightening coordination	Instead of continuing the Emporium Model, department chair and the created Task Force decided to move towards implementing AL	In response to a crisis of bad grades and little coordination, a Task Force pushed a plan for implementing AL and coordination	Started from student complaints; have had changes of AL and coordination in place for multiple decades	A couple of department leaders pushed using AL projects in Calc 1, which led to more coordination and expansion
Overview of Coordinators	Three coordinators; multi-year position	Two coordinators; multi-year position	Two coordinators; multi-year position	Four coordinators; multi-year position	Three coordinators; multi-year position
Overview of Instructors	Main: Adjuncts, Faculty Recitation: GTAs, ULAs*	Main: GTAs, ULAs	Main: Adjuncts, Faculty Recitation: GTAs, ULAs	Main: Adjuncts, Faculty, GTAs, Postdocs	Main: GTAs Recitation: GTAs, ULAs

*We use the abbreviations GTA and ULA to refer to graduate teaching assistants and undergraduate learning assistants, respectively

under each of the three drivers (two authors per one driver) to illustrate how coordinators used their positions to leverage these drivers and enact departmental changes around active learning.

Results/Findings

Our results are organized into four sections. The first three focus on each of the three drivers most closely connected to the course coordinator role. For each, we describe how the driver was engaged by coordinators at different sites; these sections are further organized by the sub-themes which emerged from our analysis process. Finally, we note connections to other drivers which course coordinators leveraged but which are not inherently tied to that role.

Building Common Tools and Resources

The details and responsibilities of course coordinators at each of the five sites evolved over time, but the nature of their roles always involved *building common tools and resources* for instructors. In looking back at what participants said about coordinators, we are better able to identify the tools that were developed, how they changed, and why coordinators focused on these particular resources. In a course coordination system, these common tools and resources are tightly tied to course content, hence our placement of this driver in Fig. 2. We also see how these common tools and resources support instructors and can be used to implement instruction that promotes active learning. Within the broad category of *building common tools and resources* for instructors, coordinator actions can be grouped as *making lives easier*, *supporting rotation*, and *direct nudging toward active learning*.

Making Lives Easier

One overarching reason pushing coordinators to build tools and resources was the goal of making instructors' lives easier. This can incentivize participation in a coordinated course in part by freeing up instructor time, removing an oft-referenced barrier to the use of active learning (Johnson et al., 2018; Shadle et al., 2017). This particular theme was witnessed at all five sites, but particularly notable at AIU, CRU, and LTU. At CRU, the common homework, exams, and grading software are all linked to a common learning management system that was created and continues to be maintained by the course coordinator, which not only supports uniformity but also "makes it easier for each instructor too so they don't need to do much" (CRU Coordinator). At AIU, the coordinators were in charge of "designing all the mid-terms, all the finals, coordinating the rooms, proctors" (AIU Coordinator); similarly at LTU, "running the exams is one of the really big things. We [the coordinators] write the exams, we coordinate who's giving it where and run around keeping track of everything while it's going" (LTU Coordinator). Coordinators across sites also

functioned as shared resources themselves, answering instructors' questions and handling issues related to grading, complaints, and general logistics. Across all five sites, the centralized system of tools and resources made instructors' lives easier, particularly in regard to the challenges of implementing active learning strategies. As such, course coordinators were in a unique position to nudge instructional practice toward the use of more active learning. At the same time, the common resources (particularly non-standard assessments such as group quizzes or polling, for example) set the tone for the course and can nudge the curriculum toward more student-centered approaches.

Supporting Rotation and Maintaining Consistency

The reality of most mathematics departments today is instructors rotate in and out of teaching courses; more and more departments rely heavily on temporary instructors or adjunct faculty to teach courses, particularly P2C2 courses (Blair et al., 2018). Two of the sites (LTU & PCU) intentionally rotated their course coordinators. The common toolbox and resources provided by course coordinators were especially helpful for new and rotating instructors and coordinators, which was key for sustainability of these programs. Turnover, such as rotating or temporary instructors, is one factor that can contribute to backsliding in efforts to change instructional practice (Henderson et al., 2011; Kezar, 2014; Reinholz & Apkarian, 2018). A PCU upper administrator noted that “she [the coordinator] developed these courses in excruciating detail. And having done that, it’s kind of in the can enough that’s not hard to hand to somebody else who can then coordinate the course the way she designed it.” When asked about the value of the coordination system, the PCU coordinator said,

for uniformity in what’s offered to the undergraduates in the courses, and also as a way [...] to support [Graduate Student Instructors] in reaching the level of teaching that we want [to] see happen and then in their own development. So they aren’t out flying solo yet.

This theme of consistency as a support for new instructors, be they new to the course or teaching entirely, was present in many interviews. An LTU coordinator succinctly summarized the rationale for uniformity: “we want uniformity of [students’] experience and the standards, and part of the way we try to achieve that is by having a lot of support for the instructors, so even the brand-new instructors, they have suggested lesson plans, suggested problems they can use.” Through the semester-by-semester turnover of instructors, coordination as a constant provided a path to sustaining positive changes and active learning.

Direct Nudging Toward Active Learning

Building common tools and resources are perhaps most obviously a driver for change when the resources nudge instructors toward particular teaching approaches. Course coordinators at all five sites acknowledged that helping instructors adopt active learning teaching practices is extremely difficult and can be overwhelming. As per the PCU coordinator, “to completely transform my classroom [...] that’s too

big a bite to eat and chew” and further “it’s too overwhelming” to have instructors who only have experience lecturing overhaul their instructional practice in a short time. To help instructors transition to using active learning strategies, coordinators provided them with resources geared toward active learning. For example, one coordinator at AIU noted that he designed discussion section activities so “they are conducive toward having [students engage in] active learning,” but also recognizes “not everything can be turned into an active learning [task].” By creating these materials, this coordinator assisted in the selection of group-worthy tasks (e.g., Lotan, 2003), which is frequently a challenge for instructors who are new to teaching with active learning strategies. In another case, the CRU coordinator provided new graduate students with a 6-step outline for running active breakout sections, including how much time to spend in small group work and guidelines for posing tasks and supporting student presentations. This document helped novice practitioners make complicated decisions in their classrooms.

Encouraging Collaboration and Shared Objectives

Faculty members identified *encouraging collaboration and shared objectives* (Shadle, et al., 2017) as one of the most important drivers in upholding a shared vision for coordinating instructional practice and improving curriculum to support student success. In order to coordinate instructional practices, instructors need to be given the space, and have the desire, to engage in dialogue about teaching. As shown in Fig. 2, coordinators can encourage this collaboration by facilitating interactions among instructors, which in turn generates shared objectives. Coordinators at all five institutions played a critical role in facilitating discussions about shared objectives, getting instructors to see the value in having these discussions, and centering these discussions on active learning principles. Furthermore, these coordinators encouraged instructors to collaboratively develop and improve course materials, contributing to an overall treatment of these courses as “community property” (Rasmussen & Ellis, 2015).

Promoting a Shared Vision through Ongoing Communication

Although communicating logistical and administrative information about coordination is necessary, coordinators at the five institutions also deliberately communicated with instructors about teaching using active learning strategies. At all five institutions, coordinators led weekly course meetings to communicate specific course objectives (e.g., content areas to highlight) and broader pedagogical objectives (e.g., encouraging student engagement, eliciting and building on student thinking). A coordinator at PCU explained, “I meet regularly with the instructors to clarify issues of content, scheduling, pace, any teaching issues that might arise, [and] help them with their personal growth as teachers.” One advantage of these meetings is teachers were growing alongside one another, forming a community of practice that supports a cohesive vision for these coordinated courses. In these meetings coordinators often set aside time for instructors to discuss challenges related to teaching and receive feedback from their peers about possible strategies for addressing these

challenges. Because coordinators were the ones leading these meetings, they were uniquely positioned to help establish an atmosphere of trust amongst instructors and also convey the importance of having these types of discussions in order to improve teaching practices.

At CU, the faculty coordinator for Calculus 1 took the lead on coordinating recitation sessions and promoting active learning among the teaching assistants who were leading recitations. Initially, faculty who were teaching Calculus 1 were giving their teaching assistants individualized instructions for what to do in recitations, leading to idiosyncratic experiences. To address this, the faculty coordinator began overseeing all recitation leaders and created a set of active learning materials to be used in recitations. The coordinator met weekly with teaching assistants to go over the course materials and discuss how to engage students. Recitation instructors were able to provide feedback and help improve the active learning activities during these weekly meetings, jointly creating a common understanding of how to elicit and build on student thinking. Thus, by leveraging their position as coordinator, the CU coordinator was able to promote more active learning in recitation sessions and help teaching assistants build a shared vision of student engagement.

Increasing Collaboration and Instructor Agency

Another way coordinators helped create a shared vision for courses was by including instructors in the development and continuous improvement of course materials. While this occurred at all five sites, it was particularly apparent at LTU, AIU, and CRU. For example, coordinators at LTU actively encouraged instructors to collaborate with one another. As one coordinator stated, instructors and coordinators “operate very much in a sort of team dynamic. There’s not just one person who can do stuff, right? It’s very collaborative.” Encouraging instructors to treat coordinated courses as “community property” was critical in getting instructors to buy-in to active learning. As the department chair at AIU described:

I think one of the biggest things is to get buy-in from the instructors, and allow the instructors to have some ownership in the entire process instead of just having it be top down...if the instructors don’t feel like they have any ownership in the process then it’s, I think it’s doomed.

By empowering instructors to take ownership of these coordinated courses, coordinators played an active role in ensuring active learning became integrated into departmental norms for teaching.

At CRU, coordinators helped unify course materials, which created a sense of cohesion and collaboration in the coordinated courses. A professor summarized the differences he saw in coordinated and non-coordinated courses by saying, “in a coordinated system, of course, we just plain meet more with each other and there is more communication, more e-mail, and there’s a lot more common materials now.” He went on to say that before coordination, “it used to be one person would make up some materials over here, another would make up materials over there and that created a slightly more disjointed feeling.” Thus, CRU coordinators played a large role

in encouraging collaboration and developing shared objectives, which had not been the case prior to coordination.

Promoting Professional Development

Across the five institutions, coordinator-led PD to support the implementation of active learning came in occasional and ongoing forms. Using Figure 2 as a guide, the coordinator-led PD initially focused on strengthening individual instructors, which in turn helps promote instructor to instructor interactions ultimately intending to impact the coordinated class. In this section, we describe what these professional opportunities looked like, the coordinators' roles, and how these opportunities supported active learning in mathematics.

Occasional PD for Active Learning

Occasional PD opportunities include pre-semester workshops and workshops carried out during the academic year. All five sites offered some form of coordinator-led or co-led pre-semester teaching workshop for graduate students and other instructors (from one to five days) who were new to teaching the active learning-focused course. Workshops at the five sites were made up of similar components: formal presentations on carefully chosen topics about teaching mathematics, interactive discussions, times for questions and answers, and (for some sites) planned times for instructors to practice teaching. The primary focuses of these workshops were to familiarize instructors with the course logistics and communicate ways active learning were intended to be embedded in the mathematics courses. One LTU coordinator mentioned several sessions run by course coordinators, including:

One [session] is specifically looking, targeting new grad students who are from underrepresented groups in the profession and to try and address issues or questions that they may have specifically about walking into a classroom and try to command the space as they will need to. And they [graduate students] need to get ready for their first classes through [a separate] open session for people who want to and say 'Alright we want to work on our first day handout, I want to work on how to figure out this lesson plan that I can pull off the web and work for me' and this is run by the coordinators usually.

Several members at the five sites view their pre-semester training as a critical support for helping new instructors start the semester. Some sites also had pre-semester PD workshops for faculty or returning instructors that were one to two days long, usually adjoining or complimenting parts of the longer workshops for new instructors. These pre-semester opportunities were a source for helping the department come together as a whole, by serving as shared learning experiences that helped lead to a common vision for excellence in teaching mathematics and engaging students. A CRU department leader explained that right before the semester, at the coordinator-led department meeting, they "broke out in smaller meetings and talked about the changes [to mathematics content and teaching] we were planning

for that semester.... and I think that was very important to listen to everybody and to be thoughtful about it.” Thus, this pre-semester meeting turned into an opportunity for different department members to come together and be heard and have a voice during a time of change.

The course coordinator at PCU led a pre-semester PD for instructors teaching coordinated courses, as at many sites in this study. Furthering their PD, this coordinator at PCU arranged to bring an inquiry-based learning workshop (led by external experts) targeted at instructors of coordinated courses, but open to all department members. The convenience of the local workshop and focus on inquiry-based learning seemed to encourage more faculty to attend. While the focus was on those teaching coordinated courses, this example of coordinator-promoted PD reached people outside the coordination system.

Ongoing PD for Active Learning

Regular instructor meetings led by coordinators were a form of PD at all five sites. These meetings focused on logistics and discussions about pedagogical topics. At CU, one coordinator said, “So the course meetings are another hour a week they set aside where they meet with the associate coordinator of the course and they talk a lot more of the practical- this is what’s coming, this is where the students struggle, this is the area that we need to really highlight.” Similarly, one LTU coordinator explained, “a lot of course meeting time was devoted to discussions of things that have happened in class... And we spent a fair amount of time [on] ‘let’s come up with five different ways you can explain what this arcsin is.’” An AIU coordinator noted these meetings helped instructors see the fun behind interacting with students differently in class. These examples of course meetings using a pedagogical focus show how these sites were providing ongoing support to these instructors in being interactive and responsive.

A department leader at PCU discussed the vital role these regular meetings played during the expansion of active learning. At the time, the plan was to move active learning beyond one day a week and a significant strategy for how he and the leaders did that was “re-orient these weekly meetings to more conversations about learning, about lesson planning, about active learning, assessment, formative assessment, so it kind of - we have that time available and we retooled that time to be more oriented to getting them [the other instructors] prepared to be engaged in this work.” This meant there were regular meetings among himself and the other leaders where they revised and discussed old and new activities, which eventually led to their common vision of all regular meetings with instructors needing to include this level of thinking about teaching and learning.

Three universities had semester- or year-long courses for graduate student instructors, usually taught by coordinators to support graduate students’ ongoing learning of effective teaching practices. In these courses, the graduate student instructors attended regularly and engaged in activities designed by the coordinator to stimulate critical thinking about teaching and learning. A CU department leader described how instrumental the coordinator had been in developing this course “and the idea

is that they [instructors] come out of that class and they have some understanding of the math education literature, and they are capable of seeing of what's going on in their classroom and thinking about it critically," ultimately helping them become independent.

At all five sites, the coordinator role is tasked with the responsibility of observing individual instructors giving feedback about their teaching. This is an example of an ongoing PD highly individualized and tailored to specific instructors. In practicality, because either the coordinator had too many other responsibilities or there were a large number of instructors, the observations were shared between the coordinator and someone else, like a co-coordinator. Coordinators at several sites mentioned that sometimes they prioritized new instructors for observations as a strategy when they did not have the time to visit everyone. As a PCU coordinator stated:

My goal is each semester to observe each instructor once, if possible. Last semester I wasn't able to observe two of them just because of timing conflicts. Like I had courses the same time they had a course so it just never worked. But the goal is to observe and see what they're doing. And the observation also helps as far as giving us a chance for a little bit of one on one talk about thinking about different teaching aspects to consider.

Connections to Other Drivers

The previous sections focused on three drivers which are closely aligned with the official role of a course coordinator. While analyzing our data for evidence of all 16 drivers, however, it became clear course coordinators' actions frequently - though not consistently across all five sites - engaged two additional drivers: flexibility and improved assessment. These drivers are not uniquely accessible by coordinators, but we provide some illustrations of how these drivers might connect to coordinators' responsibilities.

There were excerpts from the data from the five sites where the coordinators exhibited examples of helping instructors experience flexibility and independence within the coordination system and/or engaging them in opportunities to learn about assessment. At PCU, the common tools and resources were implemented and shared in ways that allow for individual instructors to make their own choices, with a coordinator noting "they do have a little flexibility." She went on to describe her attempt to teach this flexibility, specifically in using active learning, in their coordination meetings:

Like every time that you're doing it [using active learning], you're going to try for a little more of it. And sometimes that can be simply instead of talking, you're going to pause and see what they [the students] have to say, or there's three examples and you are just going to do two of them and let them do one. Just go for the low hanging fruit, and just a little more, and a little more, and you keep moving towards it [using active learning]. Because if you take someone who's like only lectured and you say, 'Now we are using active learning,' then it's too overwhelming, it's too much.

Another CRU coordinator expressed a similar attitude towards providing ideas about using active learning, but letting instructors choose when and how to use these ideas: “So anything, any technique including talk to your neighbors and I put suggestions on the table what one can do in class, but I strongly believe that’s where you have to draw the line. You can’t force somebody into using your techniques.” Both coordinators used their abilities as a coordinator to give instructors options for how to use active learning, but also established expectations of flexibility so instructors can figure it out on their own.

Across the five sites, all coordinators were in charge of assessment, mostly by constructing and overseeing exams within the coordination system. At two sites, coordinators purposefully invited the instructors to help construct these summative exams. A CRU faculty member commented “there was more collaboration” in co-constructing the exams, meaning the instructors involved were learning and discussing more things than just the problems on the exams. Similarly, the PCU coordinator talked about a time where she invited instructors to write a draft of the common exam to discuss. According to the coordinator, the initial draft was “very procedural” and “so part of our discussion last night was how we can, we want to check their procedural competence, but we also want it to be conceptual, so introducing a couple conceptual problems where they have to give some short answer justification and reasoning behind their answer.” In these two examples, the coordinator provided opportunities for the instructors to learn about making summative assessments and the teaching practices related to them.

Three sites encouraged their instructors in the coordinated courses to either make or use formative assessments in their classes. At LTU, instructors used these pre-made formative assessments to not only assess student understanding as the semester progresses, but they also used it to decide whether a student’s final grade could or should be slightly changed (e.g. from a C+ to a B-). It was not always discussed how coordinators at these sites helped instructors think through the use of formative assessments. However, a PCU coordinator described his belief about flexibility:

I’ve been very open with how they [instructors] want to use that [quiz grade]. That’s a freedom I think they should pursue, especially as grad students. If you want to test and see what you have, test your pedagogy, try something new, it’s the time to do it. So I try to support them as much as I can, and that experimentation.

Thus, for this coordinator, formative assessment was an option of the coordination system he could support as an opportunity to be flexible and this was important for graduate students learning how to know what their students understand or don’t understand.

Discussion

A course coordination system’s defining characteristics - uniform course elements and regular instructor meetings - neatly align with the *structure* frame of culture: they organize how people interact. The course coordinator has an integral role in

designing these structures, given their position, and in particular they have the opportunity to set up structures which support the use of active learning. For example, at PCU, AIU, and CU, coordinators provide instructors with daily activities to use in class which are active learning activities; by using these course elements, instructors incorporate some kind of active learning into their classes. Many course coordinators (e.g., at LTU, AIU, and CRU) have a central role in writing exams, which serve to communicate course content goals. When these exams emphasize concepts over procedures, instructors and students are under pressure to emphasize concepts over procedures in class - which is supportive of using active learning. Additionally, as seen at PCU, coordinators set the meeting agendas and thus can organize interactions around active learning in the particular course context.

Shared attitudes, beliefs, and values - or *symbols* - guide people's reasoning and actions. In this case, we consider their impact on the enactment or implementation of active learning by a variety of instructors who are part of the same coordinated course. Course coordinators cannot on their own implement or instill symbols among other members of the coordination system, but they can help set the tone. Among the sites in this study we have evidence of coordinators (with some external support) working to convey the value of active learning and collaboration. When, as at PCU, the common course materials have active learning built into them, it conveys a sense that active learning is a high priority in terms of a desirable and common student experience across sections. As with CU, course coordinators are involved in providing various types of formal and informal PD, thereby contributing to a sense active learning instruction is challenging, highly skilled work that requires real effort. By putting resources, time, etc. into facilitating active learning, coordinators (and chairs or deans, etc.) can help cultivate the belief active learning is worth supporting. While engaging in regular meetings (one structure associated with course coordination systems), course coordinators take on a leadership role and can steer conversations toward additional support for active learning and coordination; convening these meetings may also contribute to a general attitude that collaboration is expected and valued. Fostering a shared belief in the importance of collaboration contributes both to emphasizing collaboration in the classroom (a key component of active learning), and to collaboration between instructors; both of which can support agency in regard to the general instructional practice of the department.

While structures and symbols are treated as collective aspects of culture with shared implications, the *people* frame highlights the individuals within the collective who interact, recognizing them as distinct persons with their own individual goals, needs, and identities. Focusing on those individuals who are instructors of coordinated courses, we find evidence of course coordinators and coordination systems acknowledging and attending to their individuality. One example is in the offloading of instructors' time and energy to develop curricular materials compatible with active learning. This frees up the instructors' time, which allows them to both implement active learning and pursue activities that align with their own needs - be that completing a dissertation, advancing research, designing new courses, or spending more time on extracurricular pursuits. Some coordinators in our study [e.g., those at PCU and CU], made it clear in offering PD, they strive to support instructors' personal growth, which includes supporting the instructors as they pursue their own

pedagogical goals. They do not assume consistency in needs or goals across individuals, being particularly responsive to instructors' level of familiarity with active learning. As discussed previously, course coordinators at these sites fostered collaboration and the development of shared vision across instructors (and sometimes the department more broadly). This inclusion of many voices in the process is one way in which individuals' needs can be heard and respected, affording them agency as opposed to being managed.

Interactions within course coordination systems are also mediated and influenced by relational dynamics. The existence and impacts of relative status and positioning within the course coordination system, and the broader department in which that system is embedded (Fig. 1), are highlighted by the *power* frame. Ostensibly, course coordinators hold a position of relative power in relation to the instructors teaching within the system, and they often have informal as well as formal influence over instructors' teaching approaches (Apkarian & Rasmussen, 2020). At our sites the course coordinators are viewed as course experts who share, mentor, and guide others (particularly newer instructors) without engaging in authoritarian practices. Instead, they promote PD, foster collaboration, and engage instructors in developing a shared vision regarding active learning. In addition, depending in part on the status of the instructors within the system, coordinators usually do not have the power to compel instructors to do anything. This may be exacerbated in contexts where the coordinator is a short-term position and/or held by a contingent faculty member and when tenured or tenure-track faculty are teaching the coordinated courses, especially in departments with a strong culture of instructional autonomy. While full-scale refusal by instructors to adhere to coordinated elements is rare (more commonly, people simply opt-out of teaching coordinated courses), it can happen. Department policies rarely, if ever, explicitly require instructors to use the common tools and resources for active learning built by course coordinators - but when instructors see the benefit in doing so, the materials nudge practice toward more active student engagement. Across all five of our sites, course coordinators navigated their relative power and status to push instructors toward using active learning - not through mandate, but by engaging the drivers accessible from their formal role.

Conclusion

Coordinators as Change Agents

Coordinators at the five sites in this study leveraged multiple drivers, which in turn helped propagate active learning within their coordinated courses. Furthermore, when coordinators used these drivers within their role, they were also impacting the culture of the department. Thus, coordinators can be agents of change by leveraging these drivers in ways that span all four dimensions of the four frames. It is this connection between the drivers and four frames that provides the impact of the course coordinator as a change agent. By this we mean the coordinator needs to be thinking about how leveraging these drivers for active learning impacts each and all of the four frames. For example, when a coordinator is building a set of materials with

active learning for a course coordination system, they should be thinking about how the materials structure the active learning and what kind of tone it is sending, who in the coordination system might need extra nudging when using these materials, and how these particular materials might empower instructors to think about teaching. Some of the four frames are within a coordinator's purview, such as structures and symbols, and these entities are aligned with research on sustainable change (Kezar, 2014). However, it is much less clear how a coordinator can connect to some of the frames, such as power, as coordinators usually do not have the power to compel people to participate in that coordination (King et al., 2015). This power needs to come from someone with greater authority, like a department chair or dean.

Implications for Practice

The role of a coordinator does not necessarily require being a major change agent. However, as evidenced in this study, coordinators are well-positioned to go beyond the minimal aspects of coordination (as described earlier in this article). To realize their potential for transformation, a coordinator's activities need to evolve in ways that support lasting impact, particularly with infusing and sustaining active learning within coordinated courses. The levers identified in this study can help coordinators and departments envision that evolution. For example, not only running weekly meetings with instructors, but using those interactions as an avenue for informal professional development and robust conversations about pedagogy.

If coordinators are intended to be major change agents, especially change for active learning, then the most significant implication for practice is departments need to give coordinators the authority and power to be these change agents (King et al., 2015). The role of the coordinator needs to be set up so coordinators have the power and authority to access and use these drivers for active learning. For example, it isn't enough for a coordinator to just be tasked to create materials that use active learning. Without the messaging from the department that active learning is important and the power for the coordinator to enforce or nudge the active learning ideas, the materials created could just lay on instructors' desks or be used without attention to active learning. Whereas coordinators need the authority to leverage these drivers, it is vitally important coordinators are not solely responsible for the successes or failures of the coordination system. Furthermore, coordinators cannot be responsible for leveraging all 16 drivers from Shadle et al. (2017), let alone be responsible for being the only instructors who leverage the subset of drivers focused on in this study. When people in the department are "on board" then coordinators have massive potential for change, but coordinators cannot be solely responsible for people to "buy in" to using active learning or the coordination system. Figure 2 highlights the access a coordinator has to the specific drivers mentioned in this study as well as how these drivers connect with instructors and students. Believing coordinators should be solely responsible or even majorly responsible for accessing all of the drivers for change in Shadle et al. (2017) would mean the coordinator role in (as shown in Fig. 2) would become overwhelmed with drivers and overpower the interactions between the coordinator, instructors, and students.

Implications for Research

This study examined coordinators in a few case studies with relatively stable coordination systems and established active learning practices to better understand how coordinators can leverage drivers for change. More research needs to be done regarding why coordinators are pushing on these levers and how coordinators view themselves in the role of a change agent.

Since we argue an implication for practice is to not solely hold the coordinator responsible for leveraging all of the drivers, then more studies need to be done to figure out who else in the department has access to other levers, hopefully leading to a better understanding of how to distribute power and responsibility among these change levers within a department. Future research might investigate ways in which change agents without formal or official “coordinator” status might leverage these same drivers to support the implementation of active learning. We expect to see some variation in how these drivers might be used by different actors, and perhaps in their effectiveness. A related question is which drivers are well-aligned with other departmental roles, such as department head or curriculum committee chairs.

Another area for future research relates to the contexts in which coordinators are situated. Our study investigated coordinators’ activities in departments with stable and established coordination systems involving many novice instructors, and which had a focus on active learning. The extent to which a coordinator can leverage these drivers to enact and sustain change may vary across contexts. More research needs to be done on the role of the coordinator in other coordination contexts and their success or lack of success of using active learning. For example, what kind of department culture and norms are necessary for these particular levers to be available to a coordinator?

As illustrated in Fig. 1, coordination systems are embedded in departments and there are many ways in which people interact across the boundary of the “permeable box.” Therefore, a coordination system affects the culture of an entire department, as members interact and rotate through teaching assignments over time. Future research might consider the impact of coordination systems on other elements of the department, with attention to how different features (e.g., length of coordinator assignment; how frequently faculty teach coordinated courses vs. GSIs or part-time faculty) contribute to that impact.

Funding This work was funded by NSF DUE-1624643, 1624610, 1624628, and 1624639.

Declarations

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest

References

- Andrews, T. M., Leonard, M. J., Colgrove, C. A., & Kalinowski, S. T. (2011). Active learning not associated with student learning in a random sample of college biology courses. *Cell Biology Education*, 10(4), 394–405. <https://doi.org/10.1187/cbe.11-07-0061>

- Apkarian, N., Henderson, C., Stains, M., Raker, J., Johnson, E., & Dancy, M. (2021). What really impacts the use of active learning in undergraduate STEM education? Results from a national survey of chemistry, mathematics, and physics instructors. *PloS One*, *16*(2), e0247544. <https://doi.org/10.1371/journal.pone.0247544>
- Apkarian, N., & Kirin, D. (2017). *Progress through calculus: Census survey technical report*. Mathematical Association of America. http://bit.ly/PtC_Reporting
- Apkarian, N., & Rasmussen, C. (2020). Instructional leadership structures across five university departments. *Higher Education*. <https://doi.org/10.1007/s10734-020-00583-6>
- Blair, R. M., Kirkman, E. E., & Maxwell, J. W. (2018). *Statistical abstract undergraduate programs in the mathematical sciences in the United States: 2018 CBMS survey*. American Mathematical Society.
- Boelkins, M. (2018). *Active Calculus: Single variable*. Grand Valley State University Libraries. <https://activecalculus.org/>
- Bolman, L. G., & Deal, T. E. (2008). *Reframing organizations: Artistry, choice, and leadership* (4th ed.). Jossey-Bass.
- Borrego, M., & Henderson, C. (2014). Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies. *Journal of Engineering Education*, *103*(2), 220–252.
- Bressoud, D., Mesa, V., & Rasmussen, C. (2015). *Insights and Recommendations from the MAA National Study of College Calculus*. *MAA Notes*. The Mathematical Association of America.
- Bressoud, D., & Rasmussen, C. (2015). Seven Characteristics of Successful Calculus Programs. *Notices of the AMS*, *62*(2), 144–146.
- Carlson, M. P., Oehrtman, M., Moore, K., & O'Bryan, A. (2020). *Precalculus: Pathways to calculus: A problem-solving approach*. (8th edn.). Macmillan Learning.
- Cohen, D. K., Raudenbush, S. W., & Ball, D. L. (2003). Resources, instruction, and research. *Educational evaluation and policy analysis*, *25*(2), 119–142.
- Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory Into Practice*, *39*(3), 124–130. https://doi.org/10.1207/s15430421tip3903_2
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches*. SAGE Publications, Inc.
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. <https://doi.org/10.1073/pnas.1319030111>
- Gaubatz, J. A., & Ensminger, D. C. (2017). Department chairs as change agents: leading change in resistant environments. *Educational Management Administration & Leadership*, *45*(1), 141–163. <https://doi.org/10.1177/1741143215587307>
- Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952–984.
- Johnson, E., Keller, R., & Fukawa-Connelly, T. (2018). Results from a Survey of Abstract Algebra Instructors across the United States: Understanding the Choice to (Not) Lecture. *International Journal of Research in Undergraduate Mathematics Education*, *4*(2), 254–285. <https://doi.org/10.1007/s40753-017-0058-1>
- Kezar, A. (2014). *How colleges change: Understanding, leading, and enacting change*. Routledge.
- Kezar, A., & Gehrke, S. (2015). *Communities of transformation and their work scaling STEM reform*. Monograph from Pullias Center for Higher Education, Rossier School of Education, University of Southern California. Retrieved from <https://pullias.usc.edu/wp-content/uploads/2016/01/communities-of-trans.pdf>
- Khatiri, R., Henderson, C., Cole, R., Froyd, J. E., Friedrichsen, D., & Stanford, C. (2017). Characteristics of well-propagated teaching innovations in undergraduate STEM. *International Journal of STEM Education*, *4*(1). <https://doi.org/10.1186/s40594-017-0056-5>
- King, D., Cattlin, J., Ward, J., & Australia Office for Learning and Teaching. (2015). *Building Leadership Capacity in University First Year Learning and Teaching in the Mathematical Sciences: Final Report*. *Office for Learning and Teaching*.
- Lampert, M. (2001). *Teaching problems and the problems of teaching*. Yale University Press.
- Laursen, S. L., & Rasmussen, C. (2019). I on the prize: Inquiry approaches in undergraduate mathematics. *International Journal of Research in Undergraduate Mathematics Education*, *5*(1), 129–146. <https://doi.org/10.1007/s40753-019-00085-6>

- Lloyd, G. M., Cai, J., & Tarr, J. E. (2017). Issues in curriculum studies: Evidence-based insights and future directions. In J. Cai (Ed.), *Compendium for Research in Mathematics Education* (pp. 824–852). National Council of Teachers of Mathematics.
- Lotan, R. (2003). Group-worthy tasks. *Educational Leadership*, 60(6), 72–75.
- Maass, K., Artigue, M., Doorman, L.M., Krainer, K., & Ruthven, K. (Eds.). (2013). Implementation of Inquiry-Based Learning in Day-to-Day Teaching, *ZDM Mathematics Education*, 45(6).
- Martinez, A., Gehrtz, J., Rasmussen, C., LaTona-Tequida, T., & Vroom, K. (in press). Course Coordinator Orientations Toward their Work and Opportunities for Professional Development.
- Rasmussen, C., Apkarian, N., Donsig, A., Martinez, A., Tubbs, R., & Williams, M. (2021). Designing and implementing course coordination. In W. M. Smith, M. Voigt, A. Ström, D. Webb, & W.G. Martin (Eds.), *Transformational change efforts: Student engagement in mathematics through an institutional network for active learning*. AMS.
- Rasmussen, C., Apkarian, N., Hagman, J. E., Johnson, E., Larsen, S., Bressoud, D., & Progress through Calculus Team. (2019). Characteristics of Precalculus through Calculus 2 programs: Insights from a national census survey. *Journal for Research in Mathematics Education*, 50(1), 98–112.
- Rasmussen, C., Ellis, J., Zazkis, D., & Bressoud, D. (2014). Features of successful calculus programs at five doctoral degree granting institutions. In S. Oesterle, P. Liljedahl, C. Nicol, & D. Allan (Eds.), *Proceedings of the 38th Conference of the International Group for Psychology of Mathematics Education and the 36th Conference of the North American Chapter of the Psychology of Mathematics Education* (Vol. 5, pp. 33–40). PME.
- Rasmussen, C., & Ellis, J. (2015). Calculus coordination at PhD-granting universities: More than just using the same syllabus, textbook, and final exam. In D. Bressoud, V. Mesa, & C. Rasmussen (Eds.), *Insights and recommendations from the MAA national study of college calculus* (pp. 111–120). MAA Press.
- Reinholz, D. L., & Apkarian, N. (2018). Four frames for systemic change in STEM departments. *International Journal of STEM Education*, 5(1), 3. <https://doi.org/10.1186/s40594-018-0103-x>
- Reinholz, D., Rasmussen, C., & Nardi, E. (2020). Time for (research on) change in mathematics departments. *International Journal of Research in Undergraduate Mathematics Education*, 6, 147–158. <https://doi.org/10.1007/s40753-020-00116-7>
- Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). *Science education now: A renewed pedagogy for the future of Europe*. European Commission.
- Saxe, K., & Braddy, L. (2015). *A common vision for undergraduate mathematical sciences programs in 2025*. MAA.
- Schein, E. H. (2010). *Organizational culture and leadership* (4th edn.). Jossey-Bass.
- Seymour, E., & Hunter, A.-B. (2019). Talking about Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM. *Education*. <https://doi.org/10.1007/978-3-030-25304-2>
- Shadle, S. E., Marker, A., & Earl, B. (2017). Faculty drivers and barriers: Laying the groundwork for undergraduate STEM education reform in academic departments. *International Journal of STEM Education*, 4(1). <https://doi.org/10.1186/s40594-017-0062-7>
- Smith, W.M., Voigt, M., Ström, A., Webb, D., & Martin W.G. (2021). *Transformational change efforts: Student engagement in mathematics through an institutional network for active learning*. AMS.
- Speer, N., & Wagner, J. (2009). Knowledge needed by a teacher to provide analytic scaffolding during undergraduate mathematics classroom discussions. *Journal for Research in Mathematics Education*, 40(5), 530–562.
- Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., Eagan, M. K., Esson, J. M., Knight, J. K., Laski, F. A., Levis-Fitzgerald, M., Lee, C. J., Lo, S. M., McDonnell, L. M., McKay, T. A., Michelotti, N., Musgrove, A., Palmer, M. S., Plank, K. M., & Young, A. M. (2018). Anatomy of STEM teaching in North American universities. *Science*, 359(6383), 1468–1470. <https://doi.org/10.1126/science.aap8892>
- Stains, M., & Vickrey, T. (2017). Fidelity of Implementation: An Overlooked Yet Critical Construct to Establish Effectiveness of Evidence-Based Instructional Practices. *CBE—Life Sciences Education*, 16(1), rm1. <https://doi.org/10.1187/cbe.16-03-0113>
- Thaler, R. H., & Sunstein, C. R. (2009). *Nudge: Improving decisions about health, wealth, and happiness* (2nd edn.). Penguin Group.
- Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., & Grummer, J. A. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, 117(12), 6476–6483.

- VERBI Software. (2019). MAXQDA 2020 [computer software]. Berlin, Germany: VERBI Software. Available from maxqda.com
- Weaver, G. C., Burgess, W. D., Childress, A. L., & Slakey, L. (Eds.). (2016). *Transforming Institutions: Undergraduate STEM education for the 21st century*. Purdue University Press.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.
- White, K., Beach, A., Finkelstein, N., Henderson, C., Simkins, S., Slakey, L., Stains, M., Weaver, G., & Whitehead, L. (Eds.). (2020). *Transforming Institutions: Accelerating Systemic Change in Higher Education*. Pressbooks. <http://openbooks.library.umass.edu/ascnti2020/>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Authors and Affiliations

Mary Williams¹  · Naneh Apkarian²  · Karina Uhing³  ·
Antonio E. Martinez⁴  · Chris Rasmussen⁴  · Wendy M. Smith⁵ 

- ¹ Murray State University, Murray, USA
- ² Arizona State University, Arizona, USA
- ³ University of Nebraska at Omaha, Omaha, USA
- ⁴ San Diego State University, San Diego, USA
- ⁵ University of Nebraska-Lincoln, Lincoln, USA