Levers for Change: A Longitudinal Case Study of Two Departments

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University mathematics departments are making efforts to improve student success in STEM by implementing active learning in their introductory mathematics courses. These efforts are context-dependent, driving a need to understand the varying paths departments take in making these changes. In this paper we explore the change efforts of two mathematics departments that achieved varying levels of success. We take a longitudinal perspective to capture their efforts. We identify what levers these departments used, including how robustly the levers were implemented. We conclude with a discussion on how the levers identified contributed to each department's progress.

Keywords: Department change, calculus, student success

Research on departmental change, while prevalent for some time in higher education, has only recently been a focus of undergraduate mathematics education (e.g., Smith et al., 2021). In a recent research commentary, Reinholz et al. (2020) argue for an expanded research base that attends to the process of change in mathematics departments. Such research has the potential to provide both needed insights for others wanting to embark on a change initiative and to contribute to theories of change. Previous studies have focused on various aspects of departmental change including research on communities of practice, course coordination, and the intentionality needed to initiate desired change (Smith et al., 2021a), as well as research focusing on change efforts over a two-to-three-year period (Apkarian, 2018; Smith et al., 2021b). In this report we aim to contribute to this emerging research area by examining two different departmental change efforts over the span of a five-year period.

A primary reason mathematics departments in the United States (US) and elsewhere undertake transformational change efforts is poor student experience and success in the introductory mathematics courses required of most science, technology, engineering, and mathematics (STEM) majors (e.g., PCAST, 2012). In addition to traditional markers of success, such as grades, students completing calculus courses also report decreased confidence, enjoyment, and readiness (Bressoud, 2015). While the effects of these introductory courses apply to students in general, they disproportionately affect women and students of color (Bressoud, 2015; PCAST, 2012; Rocard et al., 2007, Seymour & Hewitt, 1997, Seymour et al., 2019).

High attrition and disproportionate outcomes have led to a myriad of calls to improve student experiences in introductory mathematics courses through the incorporation of active learning (CBMS, 2016; Abell et al., 2018). Analyses of efforts to improve student outcomes through active learning strategies have shown that students improve along traditional measures of success as well as affective gains, with a significant narrowing of achievement gaps for students from underrepresented groups (Freeman et al., 2014; Kogan & Laursen, 2014; Theobald et al., 2020).

Several ongoing efforts in undergraduate mathematics education are investigating departmental change efforts to better understand how mathematics departments are making these changes and what strategies might be successful (Laursen et al., 2019; Smith et al., 2021).

However, change is difficult, highly localized, and requires systemic strategies (Sabelli & Dede, 2001; Smith et al., 2021b). What works for one institution may not work for another. The two case studies reported here provide insights into various levers of change that are useful in different contexts over an extended period answering the research question: *How do two mathematics departments implement various levers of change in an effort to implement active learning in their Precalculus to Calculus 2 courses?*

Theoretical framework

We utilize Laursen et al.'s (2019) 13 levers of change to document the progress mathematics departments made with respect to changing instructional practices. Laursen et al.'s levers of change, which act on both individuals and academic units, describe a broader change theory. The levers themselves can also serve as a descriptive set of options that characterize change efforts. We selected this framework because of its flexibility in describing the factors of change at different institutions in which the levers are dependent on local context. One contribution of our work is the expansion of this framework to account for cultural and contextual factors that determine the generation and impact of site-specific levers. The theoretical framework includes three themes describing the change process.

The three themes are: (1) levers to motivate or provide rationale, (2) levers to prepare and enable, and (3) levers to stimulate and support action. Laursen et al. (2019) describe levers to motivate or provide rationale as, "Identifying the need, suggesting solutions, and prompting individual instructors or their departments and institutions to adopt [research-based instructional strategies]" (p.159). Levers to prepare and enable, as Laursen et al. (2019) state, "can best be described as offering mechanisms for change" (p. 166). That is, what structures are in place to support instructors to make changes? The third theme, levers to stimulate and support action, includes federal and private investment to support and sustain instructional change efforts - the only lever in the framework that impacts individuals and academic units together. Specifically, Laursen et al, (2019) state that, "Funding does not work directly on instructors, nor on academic units, but rather exerts secondary force on the other levers" (p. 175). We identified one additional lever, Administrative funding, that would fit under this broader definition of stimulating and supporting action. The 13 levers identified by Laursen et al. (2019) are provided in Table 1 as well as the additional change lever identified in this study shown in italics.

Table 1. Levers for change.

Lever Themes	Operating on Individuals	Operating on Academic Units
Levers to Motivate or Provide Rationale (LMPR)	1. Accreditation of certification by disciplines of states 2. Guiding documents from professional societies/leadership bodies 3. Demands from employers for specific competencies 4. Results from research	5. Models and exemplars from other institutions 6. Local data and evidence about student outcomes

Levers to Prepare and Enable (LPE)	7. Professional development 8. Resource collections or digital libraries 9. Educational technologies 10. Communities of practice	11. Collaboration with other disciplines or departments 12. Local leaders and internal change agents with a vision
Levers to Stimulate and Support Action (LSSA)	13. Federal and private funders' investments (operating on all levels and on the system as a whole) 14. *Administrative funding* (operating on all levels and on the system as a whole)	

Setting and Methods

This work is part of a larger project that studied change strategies at multiple institutions in the US to implement and sustain active learning in their Precalculus to Calculus 2 (P2C2) sequence. The research project was carried out in stages, each with its own goals and objectives. Phase 1 was a case study of six institutions that had successfully implemented active learning in their P2C2 sequence; Phase 2 was a longitudinal case study of nine departments that received nominal funding and participated in a networked improvement community (Smith et al., 2021b). Phase 3, which is the focus of this report, investigated the change strategies of departments who applied to be part of Phase 2 but were not selected. We investigate what levers influenced the progress these departments made in implementing their change initiatives. There were 38 departments that were not selected to join Phase 2, with 11 identified as having carried out at least part of their original proposal.

Of the 11 departments, six were deemed to have moderate to substantial change efforts and five were deemed to have made minimal progress towards their change efforts (LaTona-Tequida et al., 2022). Two departments from these 11 were selected for this report: One department, Mid State University (MSU), represents a modest to substantial successful change effort and one department, Large State University (LSU), represents a less successful change effort. MSU is a primarily Asian institution with very high research activity and an undergraduate student body of roughly 14,000 students. LSU has approximately 22,000 undergraduates, is a primarily white, and is a high research activity institution.

Data sources included proposals submitted by each department, audio-recorded and transcribed semi-structured interviews with key personnel in the mathematics departments, and final reports written by each department communicating their long-term progress toward their proposal goals. Our data sources span a period of five years allowing a longitudinal perspective, enabling us to evaluate change implementation over time, uncovering sustained changes and successes. Based on our knowledge of the literature, we took Laursen et al.'s (2019) 13 levers as an *a priori* coding scheme to analyze each data source but remained open to identifying additional levels (Miles & Huberman, 1994). Each department's data sources were coded individually by 2-3 of the authors who then met to discuss coding until a consensus was reached. We further organized the levers identified for each department and each data source into a table to capture changes in the use of levers over time.

Results

In Table 2 we present an overview of the levers utilized by the mathematics departments at

each institution at three time points, Fall 2017, Fall 2020, and Fall 2022. Due to space constraints, we provide detail on the 2020 data and briefly discuss the 2017 and 2022 data. Levers in bold are those we found to be the most robustly implemented and likely the most effective catalysts for change.

Table 2. Levers utilized over five years (LMPR = Levers to Motivate or Provide Rationale; LPE = Levers to Prepare and Enable; LSSA = Levers to Stimulate and Support Action).

	Fall 2017	Fall 2020	Fall 2022
MSU	LMPR4, LMPR5, **LMPR6, LPE7**, LPE8, LPE11, LSSA.13	**LPE7**, LPE10, LPE11, **LPE12**, **LSSA13**	**LPE7**, LPE10, LPE11, LPE12, **LSSA13**, **LSSA14**
LSU	**LMPR6**, LPE7, **LPE8**, LPE10, **LPE11, LPE12**, LSSA13	LMPR6, **LPE7**, **LPE8**, **LPE12**	LMPR6, LPE7, **LPE8**, LPE12

Mid State University

MSU made significant progress toward their goals, which included: 1) implementing active learning in Calculus 1 with the support of learning assistants, 2) implementing course coordination in Precalculus and Calculus 1, and 3) increasing the enrolment and retention of Indigenous students in STEM by focusing on Calculus 1.

Fall 2017. At the time of their proposal, MSU used levers from each of the three themes, with plans to expand the use of active learning, strengthening existing levers, or including new ones. In their proposal they described two levers that provided motivation and rationale, and three levers that prepared and enabled, with both themes acting on individuals and academic units. The use of local data (LMPR6) and course coordination (as a form of professional development (LPE7)) were two areas where MSU focused their change efforts in Fall 2017.

Fall 2020. By the fall of 2020 MSU expanded the use of coordination and Learning Assistants (LAs), peer-to-peer instructional aids, making use of various levers, primarily focused on levers that prepare and enable. There was no progress in data use, and MSU was limited to temporary solutions for funding.

Levers to prepare and enable. Coordination expanded in both Precalculus and Calculus 1. A permanent position was created and filled for a Precalculus coordinator and co-coordinators were incentivized through course buyouts for Calculus 1. In line with the MSU vision for coordination, Precalculus coordination evolved to include common materials and instructional support (LPE7). Instructional support was facilitated through weekly meetings where LAs and coordinators discussed areas students were struggling and strategies for attending to students' understanding. Calculus 1 coordination grew to include common midterm exams in addition to a common final exam and common materials. Notably, MSU was able to resolve resistance to coordination in Calculus 1 through teaching assignments. Permanent faculty who were at odds with course coordination were shifted away from teaching coordinated courses to teaching upper division courses.

By the fall of 2020, the LA program expanded to Calculus 1 and Calculus 2 and was the cornerstone of active learning implementation at MSU. Components of the LA program included coordination, professional development, and strong leadership. LA coordinators were responsible for creating worksheets and meeting with LAs weekly in preparation for recitation and were also

incentivized through course reduction. With respect to professional development, the new LA program director taught a semester-long pedagogy course for new LAs and provided optional workshops for instructors looking to make the best use of LAs in their classrooms. The program director also acted as a local change agent and helped promote the LA program's success to administrators.

Although coordination and the LA program previously made use of professional development, resource collections, and collaboration with other departments, these levers shifted and grew more robust as change efforts progressed. Course coordination now included communities of practice and professional development via weekly meetings with coordinators and LAs. The LA program continued to leverage collaboration with other departments but shifted from working with the Physics Department to the College of Education. Also, the creation of the LA program director position supported local leadership (LPE12) that could facilitate communication about the program's benefits to administration. In addition to these levers that prepare and enable, MSU was able to secure funding to support their active learning efforts.

Levers that stimulate and support action. The expansion of the LA program started with a round of one-time funding from the Vice Chancellor's office which supported a semester-long consultation with an LA program director from another university. An additional lever that stimulates and supports action, is *administrative funding* (LSSA14). At MSU, the Dean of the college was instrumental in securing the initial round of funding, supporting the genesis of the LA program. During this initial semester, the consultant ran an LA pedagogy course, while also training a MSU faculty member from the College of Education to run the course and fill the LA program director role locally. Additionally, the mathematics department provided funding that supported the Precalculus coordinator and Calculus 1 co-coordinator positions. Despite the positive growth in their efforts, MSU also reported in 2020 that funding for the LA program was an ongoing struggle, stating they often do not know where funding will come from until right before the semester begins.

Fall 2022. At the time of their final report, MSU described no changes to their previous coordination growth, showing a degree of sustainability and also described a robust and stable LA program. Despite previous issues securing funding, the program became a priority of the administration and funding was no longer an issue. MSU did not return to expanding their use of local data citing a need for access to "guiding principles for successful data collection, analysis, and presentation" and did not report any progress in addressing the needs of their Indigenous students, which was a need in 2017.

Overall, the change efforts at MSU included a range of levers. Analysis of local data functioned as an initial motivating lever, followed by levers included in course coordination and the LA program that prepared and enabled the department to reach their active learning goals. A significant turning point was their one-time funding through the Vice Chancellor's office, supported by the Dean of the college, which allowed them to implement the LA program, subsequently highlighting its success to administrators, and securing funding that facilitated the program's sustainability.

MSU relied on a variety of levers to different degrees to sustain their efforts until permanent funding was in place. They incentivized permanent positions for coordination and created a permanent position for the LA director. They also collaborated outside of the department. First with the Physics Department and then with the College of Education. Meanwhile all of these levers were maintained and supported by motivated local change agents. MSU's integrated

approach, which adapted based on need, appears to have contributed to their success in sustaining their efforts to implement active learning.

Large State University

LSU is an example of a department that made minimal progress toward their proposal goals which included: 1) rewriting the Precalculus curriculum, 2) solidifying the use of active learning in Calculus 1, 3) creating a mentorship program for instructors new to active learning, and 4) expanding the use of local data to refine and redesign efforts.

Fall 2017. At the time of their proposal, LSU utilized levers from all three themes. Their proposal described one lever to motivate and provide rationale and three levers to prepare and enable. LSU's levers to motivate and provide rationale acted primarily on individuals, although their levers to prepare and enable acted on both individuals and academic units. During this time, LSU's change efforts were focused on the use of local data (LMPR6) and the dissemination of active learning materials (LPE8).

Fall 2020. In the fall of 2020, LSU reported mixed progress toward their active learning objectives. Areas of improvement included more consistency in the coordinated Precalculus course and more buy-in from instructors teaching these courses. However, despite relying on similar levers, active learning efforts in Calculus 1 were stalling. Relevant to these differences is the segregated nature of the Precalculus course. At LSU, the Precalculus course is run through the Mathematics Learning Centre (MLC), and the rest of the courses in the P2C2 sequence are housed in the mathematics department. This separation likely led to differences in the strength of similar levers used.

Levers to prepare and enable. The increased use of active learning in Precalculus relied on the use of three levers: material resources, professional development, and leadership of a local change agent. Revising active learning materials for Precalculus was a major component of the LSU proposal. Despite not making progress in this revision, materials remained a central lever in their active learning efforts (LPE8). Those teaching Precalculus, housed in the MLC, were strongly encouraged to use these materials. Their use was essentially compulsory as the MLC Director, the person leading active learning efforts in Precalculus, was also responsible for hiring instructors for the Precalculus course.

In addition to materials, the MLC hosted a formal professional development meeting at the beginning of each semester (LPE7), led by the MLC Director and attended by everyone teaching Precalculus. These meetings aimed to encourage active learning and included outlines for the implementation of active learning in the classroom. A major goal of these meetings, reported by the MLC Director, was to generate buy-in for the use of active learning, particularly among newer instructors. Professional development for Precalculus continued informally throughout the semester via course coordinators who advised instructors in implementing group work. Central to the use of materials and professional development was strong leadership by the MLC Director (LPE12).

Calculus 1, run through the Mathematics Department, also relied on the dissemination of materials. However, a change in leadership led to changes in the levers reported at the time of the proposal in the Fall of 2017. The previous course coordinator for Calculus 1 collaborated with the MLC Director (LPE11), using the structure of the Precalculus program. In addition to encouraging the use of active learning materials, the Calculus 1 coordinator also utilized the communities of practice lever, meeting regularly with Calculus 1 instructors to discuss and share materials. This progress was brief, the Calculus 1 coordinator working with the MLC Director left the position, becoming Associate Dean, and no longer had a role in change efforts. After his

departure, LSU reported struggles maintaining the active learning curriculum, especially with respect to buy-in from those teaching the course.

Fall 2022. The final report from LSU reflected four levers in their change efforts: local data, professional development, resources collections or digital libraries, and local leaders or change agents. These levers were essentially unchanged from the time of their proposal, except for funding which they were not able to secure since their proposal submission. However, this consistency does not reflect the differences in progress between Precalculus and Calculus 1.

Overall, LSU used local data as an initial motivation for their change efforts. They had a brief period in which leaders in both the MLC and the Mathematics Department collaborated to promote active learning in Precalculus and Calculus 1. However, after a shift in leadership, the gains made in Calculus 1 were stifled. Precalculus continued to consistently use active learning, leveraging materials and professional development, both supported by their most critical lever, leadership.

Conclusion

As shown in Table 2, both MSU and LSU made use of multiple levers across all three points in time. Both institutions used local data to motivate and provide rationale (LMPR6). In Fall 2020 we saw that both institutions made robust use of professional development (LPE7) and that LSU also relied heavily on resources (LPE8) and local leaders (LPE12). The reliance on local leaders at LSU was problematic when the leader in the department, an ally of the leader in the Math Learning Center, left the department for the dean's office. This left both a gap in leadership in the department and left the leader of the Math Learning Center somewhat disconnected from the department. In contrast, MSU relied less on individuals and put structures in place that were sustainable. Additionally, they were actively seeking continued financial support in Fall 2020, ultimately leading to permanent funding in Fall 2022. In comparison, LSU was not able to secure continued funding beyond 2017.

At MSU there was a clear thread from 2017 through 2022 of local leadership (LPE12) and growing opportunities for professional development (LPE7), both through course coordination. MSU was also able to demonstrate how their change initiative aligned with the interests of upper administration (LSSA14). The identification of this lever for change makes a modest contribution to the change literature and levers for change detailed by Laursen et al. (2019). Another important difference that likely contributed to the differential success of the two change initiatives was structural in nature. At LSU, precalculus was run out of the Math Learning Centre, which potentially did not position the director to be a central figure in the mathematics department. In contrast, at MSU members of the mathematics departments were central and consistent change agents.

In addition to contributing to the change literature, we hope that these two stories of change provide guidance for others wishing to embark on their own departmental transformation efforts. Key takeaways from these data include caution on relying too heavily on individuals, garnering the support of upper administration (which can lead to resources for sustainability), and putting structures in place (e.g., professional development for LAs) that allow for continuity and sustainability.

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