SEMINAL: Preliminary Findings on Institutional Changes in Departments of Mathematics

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Abstract

Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL) is a five-year IUSE grant from NSF (2016-2021). The goal of SEMINAL is to stimulate and better understand how to enact and support institutional change aimed at implementing active learning in undergraduate mathematics learning environments, focusing in particular on large-enrollment entry courses: precalculus to calculus 2 (P2C2). SEMINAL is being carried out in two phases. Phase 1 consists of case studies at six institutions that have a record of successfully implementing Active Learning Mathematics (ALM). These institutions were selected to represent different institutional settings and diverse student demographics. Phase 2 consists of longitudinal, incentivized case studies of nine diverse institutions that will infuse active learning into the P2C2 sequence. Overall, Phase 1 will offer the field a retrospective account of ALM models of change that worked. Phase 2 will develop theory and insights into the processes by which change focused on ALM can unfold over time, along with affordances and constraints related to institutional change. Phase 1 data collection was completed in spring 2017, including site visits to the six targeted mathematics departments. In this article, we share both SEMINAL's theory of change for mathematics departments, and preliminary findings from the recent site visits. We discuss emerging features and aspects of the departmental cultures at these six institutions and ways in which the research of and support for ALM in the P2C2 sequence addresses the mission of the MTE-Partnership.

Keywords: active learning mathematics, improvement science, networked improvement community, institutional change

Introduction

Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL) is a five-year collaborative grant from NSF (2016-2021); the collaborative partners are the Association of Public and Land-grant Universities (APLU), the University of Colorado Boulder, the University of Nebraska-Lincoln, and San Diego State University. The goal of SEMINAL is to stimulate and better understand how to enact and support institutional change aimed at implementing active learning in undergraduate mathematics learning environments,

[1] In addition to the individuals named as authors, the SEMINAL team includes: Howard Gobstein (APLU); Robert Tubbs, David Grant and Nancy Kress (University of Colorado Boulder); Chris Rasmussen, Michael O'Sullivan, and Naneh Apkarian (San Diego State University); Allan Donsig, Nathan Wakefield, and Molly Williams (University of Nebraska-Lincoln); and John Sutton (RMC Research).

focusing in particular on large-enrollment entry courses: precalculus to calculus 2 (P2C2). Related to the Math Teacher Education Partnership (MTE-Partnership), SEMINAL works broadly to address the quality of undergraduate mathematics courses by understanding the institutionalization of cultural shifts in mathematics departments that value more active learning instructional strategies. We would argue that as mathematics departments improve student learning in the P2C2 sequence, greater numbers of students will be more motivated to pursue mathematics majors and those students who pursue secondary mathematics licensure will have more experiences of exemplary teaching and learning to draw from when they teach. Further, the SEMINAL collaboration and focus on institutional change at the department level has grown out of the MTE-Partnership Active Learning Mathematics Research Action Cluster (ALM-RAC). An *n*-dimensional problem cannot be solved with a 1- or 2-dimensional solution; SEMINAL takes a systemic approach to institutional change in mathematics.

A number of both small- and large-scale studies have shown that undergraduate students in active learning environments can learn more effectively in their classes, resulting in increased achievement and improved dispositions (Freeman et al., 2014; Henry, 2010; Laursen et al., 2014; Rasmussen & Kwon, 2007), particularly for underrepresented groups (Laursen et al., 2011). While these studies define active learning in broad terms relating to student activity, we define Active Learning Mathematics (ALM) as teaching methods and classroom norms that promote: (1) students' deep engagement in mathematical reasoning, (2) peer-to-peer interaction, and (3) instructor inquiry into student thinking (Rasmussen & Wawro, 2017). To support ALM, the curriculum should focus on key mathematical ideas, including the use of tasks that promote sense making and procedural fluency. Student activity should favor opportunities for them to propose questions, communicate reasoning, and share solutions in process. Instructor activity should showcase practices that promote student engagement and build on student thinking to advance the mathematical agenda. Undergraduate institutions are, by design, resistant to change (e.g., Birnbaum, 1991, 1999). From the organization of majors, to course syllabi, to expected classroom practices, change is challenging to implement and sustain. However, research on instructional change (Hayward, Kogan, & Laursen, 2015; Kezar, 2014) has shown that with well-articulated goals, leadership, and proper incentives, these traditions can be disrupted so that changes to the status quo can be enacted and sustained through key institutional supports that retain innovations as the new normal. We have witnessed this unfreezing-changing-sustaining process within Phase 1 math departments (e.g., Apkarian, Bowers, O'Sullivan, & Rasmussen, in press; Carreon, DeBacker, Kessenich, Kubena, & LaRose, 2017; Webb, Stade & Grover, 2014).

SEMINAL's primary research question is: What conditions, strategies, interventions, and actions at the departmental and classroom levels contribute to the initiation, implementation, and institutional sustainability of active learning in the undergraduate calculus sequence (Precalculus through Calculus 2) across varied institutions? We adopt an ecological framework to institutional change, envisioning changes nested in a variety of interrelated contexts: departmental, institution, and community cultures, as well as the knowledge and beliefs of all engaged stakeholders. Figures 1 and 2 illustrate our initial frameworks for the key components of change at the classroom and departmental levels.

SEMINAL is being carried out in two phases. Phase 1 consists of case studies at six institutions that have a record of successfully implementing Active Learning Mathematics (ALM) and that represent both diverse institutional settings and student demographics. The six institutions include the three research collaborative partners (outlined above) and three additional institutions (Sam Houston State, University of Illinois at Chicago, and the University of Michigan). Phase 2 consists of longitudinal, incentivized case studies of nine diverse institutions that will infuse active learning into the P2C2 sequence. Phase 2 institutions will be expected to work together in a Networked Improvement Community connected to the MTE-Partnership ALM-RAC. By applying improvement science to departmental and institutional change, Phase 2 institutions will engage in Plan-Do-Study-

Act cycles to engage in a process of continuous improvement of their high-enrollment undergraduate P2C2 courses.

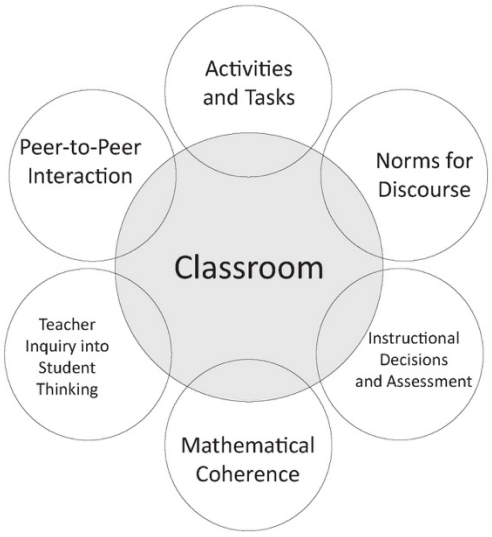

Figure 1. ALM at the classroom level.

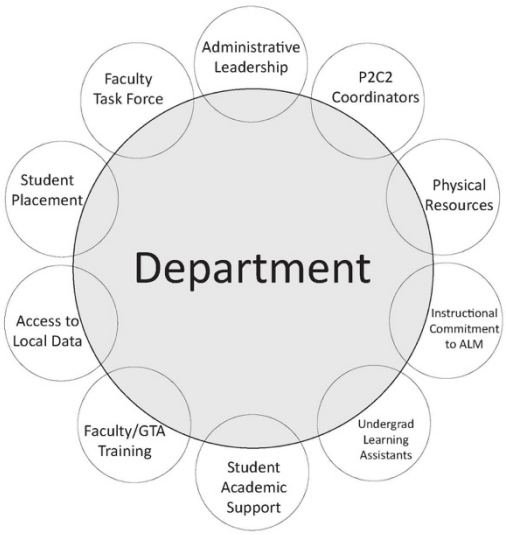

Figure 2. ALM at the departmental level.

Overall, Phase 1 offers the field a retrospective account of ALM models of change that worked. Phase 2 will develop theory and insights into the processes by which change focused on ALM can unfold over time, along with affordances and constraints related to institutional change. Phase 1 data collection was completed in spring 2017, including site visits to the six targeted mathematics departments.

Methods

SEMINAL research is studying institutional change in multiple settings, and at various stages of the change processes, through coordinated research and evaluation efforts. During Phase 1, members of the research and evaluation team conducted separate two-day site visits at each of six institutions whose mathematics departments were identified as having a sustained culture of active learning in P2C2 courses. Using a design research model to iteratively study institutional change at each research site, we are developing case studies of institutional change (Yin, 2003) in the diverse contexts. Each mathematics department implementing ALM will be one case.

To determine how classroom and departmental elements contribute to or serve as barriers to student success, it is important to define student success in high-enrollment undergraduate mathematics courses. In the short-term, student success is measured by student end-of-course grades to calculate the percentage of students earning a C (pass) or better, and student attitudes toward mathematics. Longer-term measures of student success include student retention rates in college, intentions to pursue STEM majors, and course-taking patterns (taking more mathematics courses in subsequent semesters).

Each of the six institutions being studied agreed to complete a survey designed to capture department culture and social networks. SEMINAL asks all P2C2 instructors to complete the PIPS+: Postsecondary Instructional Practices Survey, with additional demographic and SEMINAL-specific items (Walter, Henderson, Beach, & Williams, 2016). SEMINAL also surveys students in P2C2 courses, with an adapted version of PIPS+ for students (SPIPS+), to capture instructional practices, student intent to persist in STEM, and students' beliefs and attitudes toward mathematics in general and ALM in particular. During the site visits, SEMINAL teams conducted observations of

P2C2 courses, utilizing the Mathematics Classroom Observation Protocol for Practices (MCOP^2; Gleason & Cofer, 2014).

If institutional change to increase student success in mathematics were easy to accomplish, everyone would already be doing it. To determine the barriers that make this work challenging and the strategies that are employed to overcome these barriers, the institutional change processes at the research and collaborating campuses will be documented internally by the participating institutions and externally by case study teams that represent both researchers and the grant's external evaluator. The Phase 1 site visits mainly included interviews of a wide variety of P2C2 stakeholders at the classroom, department and campus levels. As affordances, constraints, and patterns of change emerge from cross-institutional analyses, we will articulate potential pathways for change for mathematics departments interested in improving student success in high-enrollment undergraduate mathematics courses. We will also investigate the extent to which formal and informal leadership at each institution at various levels influences the implementation of an ALM model in P2C2 mathematics courses. As analyses for Phase 1 unfolds further, we will use a grounded analysis (Strauss & Corbin, 1998), informed by our institutional frameworks to develop themes within and across our cases to develop models of institutional change for active learning that with inform our approach to Phase 2.

Preliminary Findings

Consideration of Institutional Context

Still in its first year, the SEMINAL research and evaluation teams are in the process of analyzing the data collected during Phase 1. Across year 2, analyses will be continued, and cross-case analyses will begin. One of our key initial determinations is that we needed to expand our change frameworks beyond the classroom and department levels, to seriously include the institution and community levels. Thus, during Phase 1 site visits, in addition to interviewing mathematics faculty and instructors, we also interviewed faculty in mathematics client disciplines (e.g., physics, chemical engineering). Figure 3 shows our revised framework, that considers ALM in the interrelated contexts of the classroom, department, institution, and community. Although Figure 3 shows nested contexts, all of these contexts interweave in complicated ways. The SEMINAL team is working to create diagrams to depict key features of institutional and community contexts. An early draft of key institutional contexts is shown in Figure 4; preliminary key community contexts are shown in Figure 5.

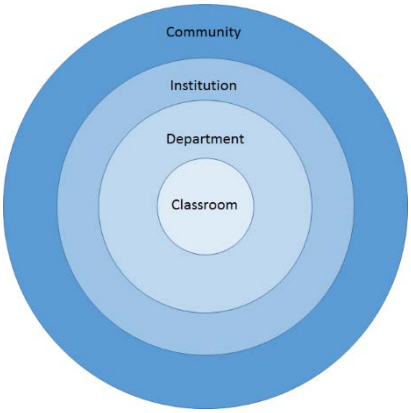

Figure 3. Relevant ALM contexts.

The communication norms of a campus seem to play a pivotal role in sustaining ALM. We have observed different norms for communication among departments, and among central administrators, deans, and department chairs. In all Phase 1 institutions, there were at least a few strong connections between the mathematics department and central administrators who value active learning.

Related to resources for instruction, Phase 1 institutions featured administrators (central administrators and department administrators) who were willing to pay the costs of improved instruction. It is more resource-intensive to have smaller classes or more instructors per course to implement active learning, compared to large lecture courses. Resources are also important at the community level. Departments moving toward ALM also

incurred costs related to course redesign and instructor professional development. Resources for infrastructure, faculty, and students (including campus norms for housing and/or commuting) all influence the successful institutionalization of ALM.

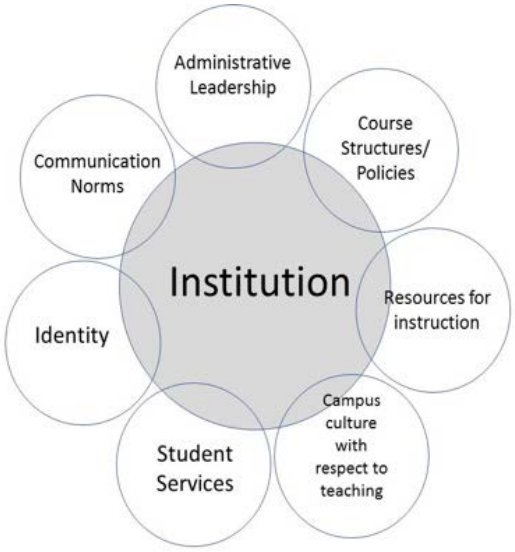

Figure 4. Preliminary institutional contexts.

Figure 5. Preliminary community contexts.

SEMINAL is just beginning to explore identity as an institutional feature; it seems to encompass the university mission, research, teaching, departmental culture, and student population. Community identity also impacts ALM in P2C2 courses, including who takes P2C2 courses and how valuable it is for community members to be mathematically literate.

Placement

While the original SEMINAL framework identified student placement as a departmental context (Figure 2), we found this to be more of an institution-level context in some of the Phase 1 sites. More than one campus utilized math placement to also determine placement in introductory science courses (e.g., chemistry, physics). Also, at some campuses, the placement test (e.g., ALEKS) was determined by central administrators. No campus is completely satisfied with their placement procedures; many faculty who were interviewed expressed concerns that current placement procedures may be at odds with campus goals for increased equity. SEMINAL plans to continue to investigate placement procedures, especially as some participating campuses are changing these procedures.

As the ALM Research Action Cluster in the MTE-Partnership began to consider levers for change, unacceptably high D-Fail-Withdraw (DFW) rates were commonly cited. For at least two Phase 1 institutions, the rates of grades of DFW were the original impetus for change; for other Phase 1 institutions, dissatisfaction with calculus recitations was the original change point. As Phase 1 institutions examine their student data, including DFW rates and course-taking trajectories, another preliminary finding is that on some campuses a grade of C does not actually prepare a student well enough to pass the subsequent course. At one campus, the percentage of students who pass Calculus 1 after taking precalculus on campus increased by 10 percent after comprehensive implementation of ALM. However, this overall 63 percent passing rate in Calculus 1 by students who took precalculus at the college masks the fact that while about 85 percent of students who earned an A in precalclulus

were able to pass Calculus 1, under 30 percent of students who earned a C in precalculus were able to pass Calculus 1. Given this finding, SEMINAL is seeking to explore course taking trajectory and grade data from all of the Phase 1 institutions, and to implement some PDSA cycles to investigate what policy changes could be made to address these findings.

Consideration of Community Context

By conducting site visits using an improvement science framework, the SEMINAL team collected information about the contexts of P2C2 courses. While our original hypothesis narrowed our scope to the classrooms and departments, the site visits convinced us we needed to consider both the broader institutional contexts and the community contexts. For instance, Sam Houston State University recognizes that many of their students are first-generation college students, which influences the design of community, campus, and department support structures. Finding ways to ensure students are able to negotiate housing and finances, enrollment in courses, and course-taking decisions that could make or break the completion of the mathematics major are understood and supported at multiple levels. Community contexts also arose for the University of Illinois Chicago, where the university has dual identities as both a research-intensive university and a community-serving institution for under-represented and commuter students. Being based in Chicago, they are in direct competition and impacted by other local universities, which has implications for their desire for high-quality P2C2 courses that meet their students' needs.

Conclusion

As we conclude Phase 1, SEMINAL is actively seeking proposals for institutions to participate in Phase 2. Institutions chosen will receive some project funds (approximately $50,000-100,000) to support efforts to enact institutional change related to implementation and/or scaling up of ALM in the P2C2 sequence. After selection of awardees is made in late 2017, Phase 2 institutions will participate in a networked improvement community, and will use the framework of improvement science, along with what will have been learned from Phase 1 of SEMINAL, to guide their change processes. This network will be connected to the MTE-Partnership ALM-RAC network, who have been working to institutionalize ALM on their campuses for the past five years.

The SEMINAL research and evaluation teams are also actively analyzing Phase 1 data, with the goal of creating a handbook of ALM and institutional change based on these analyses in 2018. Such a handbook will carefully describe the contexts of each of the six institutions, and then have sections about each of the key change features (at the classroom, department, institution, and community levels). SEMINAL plans to work with the MTE-Partnership network to disseminate findings, thus helping universities across the country improve their campus cultures related to ALM, and thus their P2C2 student outcomes.

Institutional change literature (e.g., Elrod & Kezar, 2016; Kezar, 2014) suggest a key reason effective practices fail to successfully scale up is when stakeholders ignore contextual features. SEMINAL believes for *n* institutions successfully implementing ALM, such instantiations of institutional change will take *n* different (but not disjoint) forms. A key challenge is understanding the contexts at the classroom, department, institution, and community levels, and determining which of those contextual features are key to implementing and sustaining positive changes. Improvement science seems to be a promising approach to effecting sustained institutional change to improve student outcomes in mathematics.

For More Information

- Website: http://www.aplu.org/seminal/
- Contact David Webb (dcwebb@colorado.edu) or Wendy Smith (wsmith5@unl.edu) for general inquiries. Contact seminal@aplu.org for questions about the Phase 2 opportunity.

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