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## Active Learning Mathematics at the University of Nebraska-Lincoln

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One of the top two goals of the Math Teacher Education Partnership (MTE-P) is to increase the quantity of secondary mathematics teachers prepared at the partner institutions by 40%. Such an increase necessarily involves more undergraduates interested in mathematics. Typically, before undergraduates become mathematics majors, they take one or more freshman-level mathematics courses (precalculus to calculus 2). However, in 1987 mathematicians reported that “as many as 40% of undergraduates were failing introductory calculus, and even those who passed did not appreciate the subject’s relevance” (Wilson, 1997, p. A12). More recently, the Characteristics of Successful Programs in College Calculus (Bressoud, Carlson, Mesa, & Rasmussen, 2013) showed failure rates (grades of D, F or Withdraw) ranged from an average of 25% at Ph.D.-granting universities to an average of 37% at regional comprehensive universities. Thus, improving students’ experiences in freshman-level mathematics courses is a logical prerequisite to increasing the number of undergraduates who seek to become mathematics teachers.

In recent years, research overwhelmingly has shown that active learning strategies are effective at increasing student success in undergraduate science and mathematics courses (e.g., Bressoud & Rasmussen, 2015; Freeman et al., 2013; Laursen et al., 2011; 2014), particularly for underrepresented groups of students. Thus, the MTE-P chose to focus one of its five initial Research Action Clusters around Active Learning Mathematics (ALM RAC). The Department of Mathematics at the University of Nebraska-Lincoln (UNL) was one of the founding members of this ALM RAC, having already begun efforts to improve precalculus courses. The mathematics department also embraced the MTE-P *Networked Improvement Community* (NIC; Bryk et al., 2015; Martin & Gobstein, 2015) model. Working as part of the ALM RAC has allowed UNL to accelerate course improvements by building on the learning of other ALM RAC institutions. Further, the positive results of implementing active learning in precalculus has institutionalized these practices at UNL.

UNL utilizes the ALM RAC definition of active learning: *We define 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. In*

support, 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. This classroom description is represented in Figure 1.

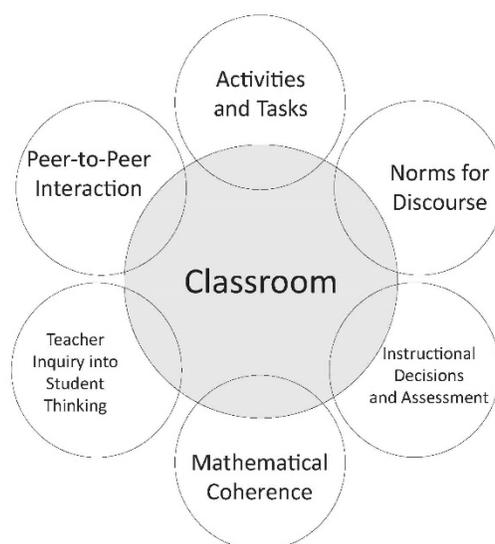


Figure 1. Classroom-level ALM features.

Adopting an active learning approach to instruction is only one component of a larger institutional transformation to improve student success in mathematics. Besides faculty leadership, active campus and departmental leadership are also critical to successful institutionalization of ALM. Departments committed to institutional transformation attend to student data, particularly placement data, student trajectories through courses, and student success. In addition to effective leadership and intellectual resources, physical resources such as classroom furniture and class minutes per week also can contribute to or hinder institutional transformation—represented in Figure 2. UNL has committed to institutional change at the departmental and classroom levels. The overall purpose of this brief report is to summarize the UNL efforts to transform freshman-level mathematics courses and raise student success.

## Background

The research team at UNL collects extensive data each semester about the students in the precalculus and calculus courses. This brief report focuses on documenting the institutional changes at Nebraska, drawing mainly on the quantitative data collected about students and courses. UNL joined the Big Ten in 2011, and started to focus on raising the six-year graduation rates and freshman retention rates. At UNL, over two-thirds of freshmen take a mathematics course in their first semester; no other department even garners half of first-time freshmen

enrollment. Thus, freshmen retention correlates very highly with passing precalculus and calculus mathematics courses.

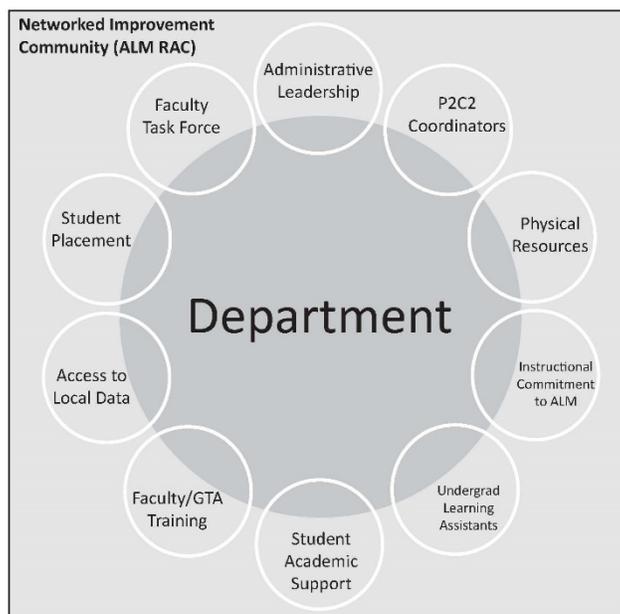


Figure 2. Department-level ALM features.

At UNL, fall enrollment in mathematics courses tends to be approximately double that of spring enrollment. In Fall 2015, approximately 1,500 students took one of four types of precalculus courses, and approximately 2,000 students took calculus 1 or 2. Precalculus courses at UNL include: Intermediate Algebra (3 credit hours but does not count as mathematics credits), College Algebra (3 credit hours), Trigonometry (2 credit hours), and College Algebra & Trigonometry (5 credit hours; the union of the previous two courses listed).

Table 1

*Relevant parameters of Active Learning Mathematics context at UNL*

UNL – By the Numbers (Fall 2015)	
All Students	25,260
Undergrads	20,182
First Time Freshmen Average ACT Score	25.2
University-wide Freshman/Sophomore Retention	82.5%
6-year graduation	67.0%
Math GTAs	77
Math Tenure-track Faculty	29

## Methods to Improve Freshman Success in Mathematics

With substantial variation across sections, historical success rates<sup>1</sup> in College Algebra and College Algebra & Trigonometry (2007-2011) hovered in the low-60% range. The first efforts to improve these courses involved an emporium model, in which students worked at their own pace through materials in a computer lab, with graduate teaching assistants (GTAs) available to answer questions. That model was quickly abandoned in 2012, at which time the focus shifted to active learning approaches.

UNL invested considerable resources into implementing active learning, addressing all of the components in Figure 2. Success rates now are steady at around 80%. Key efforts included First-Year Mathematics Task Force, hiring a Precalculus Coordinator, strong administrative leadership and physical resources, the use of Learning Assistants, a course readiness activity, and an effort to improve students' online homework experience. Each is discussed next.

The First-Year Mathematics Task Force was a faculty committee dedicated to improving freshman-level mathematics courses; a key role was to evaluate the quality and difficulty of the exams, to provide assurance that improved success rates were not due to lowering of mathematical standards. The task force also marshalled and made sense of local data, to help inform the ongoing efforts.

UNL hired a full time assistant professor of practice to serve as coordinator for the four precalculus courses and to oversee the training and ongoing mentoring of GTAs. Close coordination of the courses includes not just a syllabus and common exams, but also detailed lesson plans, to reinforce a model of class time dominated by students doing mathematics in groups, and engaging in small-group and whole-class discussions to make sense of the mathematics. The first-year GTAs are responsible for teaching their own course (in sections of 40 students), and they are required to take a year-long teaching seminar. To balance this demand, the GTAs' first-year teaching assignment is one course each semester; in later years, GTAs teach two courses in the fall and one in the spring.

Due to strong administrative leadership, multiple classrooms on campus were renovated to include moveable tables and chairs, and whiteboards all around the room, and then dedicated to house math courses. Additionally, understanding that active learning takes more time than lecture, while the credit hours remained constant, the minutes per week in College Algebra were increased from 150 to 225, and the minutes per week in College Algebra & Trigonometry were increased from 250 to 300.

A final effort was the implementation of Learning Assistants into the precalculus and calculus mathematics courses. The department hires undergraduate learning assistants, initially

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<sup>1</sup> Success here means the student earned a C or better in the course (or Pass if taken pass/no pass).

grant-funded, to help in the precalculus courses and to serve as an additional instructor to facilitate group discussions.

In addition to the above activities, the Department of Mathematics also decided to institute a test on the first day of class, covering prerequisite material, and which can serve as a check on course placement. The department quickly learned to call this a “course readiness activity” rather than “prerequisite mastery exam”; students who did not pass on the first day were allowed to retake the test once per day for two weeks in the college testing center. Students could get review packets and work on these in the Math Resource Center (tutoring room staffed by GTAs and undergrad math majors) with their instructor or learning assistant.

This course readiness activity sorted students into three groups: those who passed on the first day (know the material); those who eventually passed (invested time to relearn material); those who never passed (no obvious time investment). Most of the “never passed” group never attempted to take the test in the testing center at all. This course readiness activity has proved to be incredibly predictive. Those in the first two groups (pass/eventually pass) average 80% on the course exams (three exams + final), with 75% of students in those groups earning grades of 75% or higher. Students in the “never passed” group averaged under 60% on course exams, with nearly 75% of these students earning grades below a C. Among the students who do not pass the course readiness activity on Day One, the chances to retake the test seem to help distinguish students’ “college readiness” skills of being able to engage in positive habits such as studying and seeking help.

Once the mathematics department realized the predictive ability of this course readiness activity (Fall 2014), the department sought to implement interventions with the “never passed” group in Fall 2015. The interventions targeted math skills, and were successful in raising student exam averages higher than the previous years’ “never passed” group, but not to the level of those students who did pass this initial test. Future interventions may need to find a way to incorporate broader “college readiness” skills.

Finally, an internal grant allowed two faculty members to improve the online homework experience for students. UNL uses WeBWork, an open-source platform, to deliver online homework assignments to students, as a way to provide students opportunities to practice what is learned in class. WeBWork was adopted in 2013, following the previous use of MyMathLab. Students get multiple attempts per item; the online system allows students to know immediately if their answers are correct. Yet, knowing an answer is incorrect almost never helps a student determine how to correctly solve a problem.

Students were initially frustrated that WeBWork lacked the “hint” feature of MyMathLab, in which a student could see the same problem (with different numbers) worked out in a step-by-step fashion. However, this type of hint emphasizes procedure memorization,

and the department wanted to emphasize conceptual understanding. Thus, through this internal grant, experienced GTAs and several high school teachers were hired to create more conceptual hints to target common errors or misconceptions. These new hints were designed to be the question an instructor would ask, or a reminder an instructor would give to students who were stuck on a problem, such as the one shown in Figure 3.

(1 point) **local/setChapter2/Chapter2Section2S1.pg**  
 Let  $f(x) = \frac{x-2}{x+4}$  and let  $g(x) = \frac{1}{x(x+4)}$ . For what value(s), if any, are the functions undefined? If there are multiple values, enter each value separated by a comma.

The function  $f(x)$  is undefined when  $x =$   .

The function  $g(x)$  is undefined when  $x =$   .

**Hint**  
 To find where a function is undefined, consider possible inputs for the function that have undefined outputs. Remember, dividing by 0 is undefined.

Figure 3. Sample improved hint offered in the WeBWork environment.

WeBWork allows a department to keep track of problem-level data, so the Department of Mathematics could track the questions with and without hints. Students earned more points, on average, on homework questions that included these new hints. In response to an end-of-semester survey, 84% of students reported using the hints at least once, and 87% of those students found the hints to be at least occasionally helpful, demonstrated in Figure 4. In crafting hints, the goal was to address the most common misconceptions, knowing that the hints would not be able to comprehensively address every possible student error.

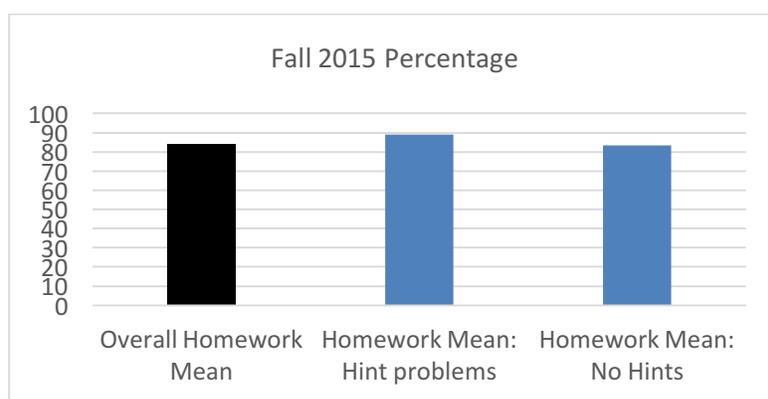


Figure 4. Results of student survey showing the difference in homework scores on problems with and without hints.

## Conclusion

The research team at UNL continues to be involved in the ALM RAC. With active learning well-established (successfully) in precalculus courses, the focus in 2016 is on extending active learning strategies into calculus 1 and calculus 2 courses. In those courses, taught in large (150) lecture with small (25-30) recitations, the lectures are now infused with numerous clicker questions, which the instructor can follow up by having students discuss with students nearby. The recitations have shifted from 100 to 150 minutes per week, and instead of serving as times when students watch a GTA solve homework problems, now these recitations serve as time for students to work collaboratively on new problems.

The WeBWork hints are expanding to other courses (initial funding focused on College Algebra). A future goal is to create some short video hints, in which an instructor gives a very brief (less than 3 minutes) lecture about the topic, covering more of the common misconceptions.

Finally, the UNL research team is part of a new grant from the National Science Foundation, titled *SEMINAL: Student Engagement in Mathematics through an Institutional Network for Active Learning*. SEMINAL seeks to study transformed departments like those at UNL, University of Colorado-Boulder, and San Diego State University, as well as departments at earlier stages of transformation, both inside and outside the ALM RAC. By focusing on the Networked Improvement Community model, what SEMINAL learns about departmental transformation can be rapidly disseminated to the rest of the ALM RAC, as well as to the MTE-P more broadly, to support the propagation of improved student success.

## For More Information

- URL – [www.math.unl.edu](http://www.math.unl.edu)
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