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Using Active Learning Strategies in Calculus to Improve Student Learning and Influence Mathematics Department Cultural Change

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Keywords

calculus, active learning, teacher change

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Introduction

Nationally, less than 40% of students who begin college in pursuit of a science, technology, engineering or mathematics (STEM) degree complete in one of these disciplines (PCAST, 2012). Furthermore, almost a quarter of the students who leave STEM fields cite low grades in the early years of study as a factor for their decision to leave. These claims are supported by earlier work from Seymour and Hewitt (1997) who identified seven reasons students leave these disciplines, including feeling overwhelmed by the rigor of courses and dissatisfaction with instruction or the climate found within the discipline. Their findings of poor science, math and engineering teaching and lack of student preparation for the mathematics and sciences support the need for identifying not just more educational innovations, but specifically those having a *significant impact* on student learning (ASEE, 2012). Charged with the call from PCAST (2012) to study the attributes of successful math courses for dissemination of best practices, researchers developed the MATH-GAINS project to enhance math learning environments. Using active learning strategies proven successful in other STEM disciplines, researchers aimed to arm faculty with the necessary tools to enrich instruction and improve student learning within the calculus sequence.

The goal of this research – MATH-GAINS (Growing as Adaptive Instructors) – was to create an ecosystem where an influential number of the Department of Mathematics faculty at a large metropolitan university persistently and sustainably applied evidence-based practices in their teaching of calculus courses, the courses considered as a *gateway to success in STEM disciplines* (PCAST, 2012). As a result of improved instruction, MATH-GAINS proposed to positively affect student learning, retention and graduation within STEM. By the end of the MATH-GAINS effort six faculty and ten math graduate students (many of whom will teach post-secondary math upon graduation) were provided training and support to apply evidence-based practices in their math courses. These faculty members and graduate teaching assistants (GTAs) *annually affected over 900 students*. Data collected during this project continues to add to the growing body of knowledge of how research-based instructional strategies designed in other STEM disciplines work in math courses, as well as the community's understanding of the critical factors that influence math faculty's teaching practices.

The MATH-GAINS project was grounded in the recommendation from the 2012 PCAST Undergraduate STEM Education report, to identify and broaden implementation of research-based instructional strategies and address the problem of excessively high failure rates in introductory mathematics courses at the undergraduate level, in order to open pathways to more advanced STEM courses. Project activities were designed in such a way to ensure the Mathematics Department could sustain a culture of using evidence-based teaching practices in math courses with a plan to use state and national existing partnerships to disseminate best practices. The objective of this paper is to provide details on how the project was conceived and implemented; instruments, research methodologies and active learning strategies used; and examples of faculty projects and preliminary results of the study.

Project Overview

The researchers desire to provide a thorough understanding of the MATH-GAINS project with the goal of allowing replication across other institutions. To assist, this

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paper outlines the detailed objectives of the project, why the interdisciplinary team was formed, how each phase of the project was implemented broken down by faculty and student components and the instrumentation and methodology used in the research.

Objectives

Several objectives were identified to guide the research with the role of MATH-GAINS faculty increasing in responsibility through the sequential path of project activities.

Objective 1 – Develop and Retrain. Two Learning Communities (one in Year One and one in Year Two of the project), consisting of three faculty and five GTAs, participated in a year-long project with on-going training.

Objective 2 – Implement and Reinforce. Each year, the learning community participants implemented self-selected evidence-based practices during both fall and spring semesters.

Objective 3 – Disseminate. Faculty participants from each year's learning community disseminated their projects to (a) other on-campus faculty (local), (b) other state institutions (regional) and (c) faculty from institutions in other states (national) through existing consortia and partnerships.

These objectives allowed researchers to meet the goal of creating an ecosystem of mathematics faculty persistently and sustainably applying evidence-based practices in their teaching of calculus courses. Objective 1 which provided for faculty development with consistent reinforcement of the strategies used in the classroom was considered the most critical for the success of the MATH-GAINS effort. For this reason, the supporting activities will be deliberately detailed in the faculty section of this paper.

Implementation

A very thoughtful process went in to selecting the right mix of faculty partners to develop and implement the MATH-GAINS project. An interdisciplinary team from physics, education, math, the Faculty Center for Teaching and Learning (FCTL) and the Center for Initiatives in STEM (iSTEM) were hand-picked with the necessary expertise for the project's success. Ensuring the project had the proper support within mathematics at all levels, the chair and an associate professor from the department led the project. Faculty from education, physics and FCTL were chosen to provide appropriate training and professional development to the faculty participants, assess the level of implementation of evidence-based practices, prompt faculty reflection and suggest avenues for improvement. The physics, education and FCTL faculty members had experience personally implementing evidence-based teaching practices and designing evidence- based curriculum for use by other faculty and GTAs. Additionally, they had expertise in assessing student learning, using protocols to observe instruction, and interviewing faculty about their teaching practices. The iSTEM Executive Director tracked the progress of the students in the target cohort and made the necessary arrangements to ensure registration for MATH-GAINS calculus courses, student group coding and data collection.

Prior to commencement of the project six mathematics faculty were selected to participate over the course of the project – three in year one and three in year two. Each faculty member was assigned to teach a section in the calculus sequence (Calculus with Analytical Geometry 1, Calculus with Analytical Geometry 2 and Calculus with Analytical Geometry 3) for both the fall and spring terms of the same academic year. Faculty formed a learning community and attended personalized professional development training. After being immersed in the research literature, they were provided with a menu of evidence- based teaching practices to implement in the classroom, from which they selected one or more practices to implement in the subsequent two semesters. Non-project faculty experienced in implementing evidence-based teaching practices and designing evidence-based curriculum served as mentors for the Year One faculty. Year One faculty then served as mentors to Year Two faculty participants. Five graduate teaching assistants (GTAs) were selected to assist the faculty each year, for a total of 10 GTAs. Both faculty and GTAs participated in professional development activities in support of the MATH- GAINS experience.

The mathematics courses included in MATH-GAINS (MG) contained no specific designation that would assist students in identifying which sections were included in the project. This allowed registration for the courses to be random. All students meeting the appropriate prerequisites for the calculus sequence had an equal opportunity to register for a MG course. After the first term of participation in a MG course, students were invited to continue into the next MG course in the Calculus sequence if they desired. Once current MG participants were registered, the remaining seats in the section were opened to the general population. Table 1 includes the number of students registered in MATH-GAINS for each term.

Table 1. MATH-GAINS student enrollments by course, term and year of the project

Course	Year One		Year Two		Total
	Fall	Spring	Fall	Spring	(course)
Calculus 1	392	271	439	414	1516
Calculus 2	49	49	48	49	195
Calculus 3	49	49	49	50	197
Total (term)	490	369	536	513	1908

Student demographic and performance data were collected using university system databases and faculty course records. All student perception and concept knowledge data were collected in the various calculus courses each term. The Characteristics of Successful Programs in College Calculus (CSPCC) gauged student attitudes and efficacy about learning mathematics. The instrument was administered using Qualtrics survey software in a pre and post-test format during the first and last weeks of each term. The Calculus Concepts Inventory (CCI) measured the understanding of Calculus concepts. The CCI was administered as a paper survey utilizing Scantron forms for easy data collection and was also offered in a pre and post-test format at the beginning and end of the term. The student consent process occurred in class during the first week of the semester. Students were informed that participating in the research was voluntary and had no bearing on their course grades. Students provided consent on the Undergraduate Explanation of Research online via Qualtrics.

Data on faculty attitudes, beliefs and efficacy were collected using a number of methods. To measure demonstrated positive change in attitudes and beliefs about the efficacy of evidence-based teaching practices in the identified courses, two survey instruments were used in a pre and post-test format: Culture, Cognition, and Evaluation of STEM Higher Education Reform (CCHER) (Hora, 2011) and a calculus teaching efficacy questionnaire modified from Gill, Ashton and Algina (2014). Data were collected electronically using Qualtrics survey software. To provide further validity of belief change beyond simple self-report, two additional measures were used: (a) ratings of teacher scenarios (Bullough, 2015; Gill, Ashton & Algina, 2014) and (b) examinations of faculty rationales for their instructional decisions during interviews and training sessions (Gill & Hoffman, 2009). Classroom observations using the Reformed Teaching Observation Protocol (RTOP) (Piburn, Sawada, Falconer, Turley, Benford, & Bloom, 2000) were used to gauge the extent to which faculty implemented the evidence- based practices. RTOP was chosen for MATH-GAINS due to the focus on the extent of the implementation of evidence-based teaching practices. Pre, mid and post-implementation observations were conducted by a n external observer prepared in utilizing the protocol. In addition to being the instrument used by the external observers during MATH-GAINS' assessment, the RTOP was used as a formative assessment tool through peer observations conducted by other participants in the learning community and by the assigned mentors.

In addition to professional development workshops, every semester the GTAs used a mixed reality teaching simulator to engage in virtual practice. Aimed at helping GTAs to acquire and refine their skills through the use of TeachLivE technology (Andreasen and Haciomeroglu, 2009), the virtual practice sessions integrated immediate feedback and reflection in between short virtual teaching sessions. With the TeachLivE technology, GTAs focused on implementing strategies to facilitate group discussion including – providing specific feedback, asking higher-level questioning and practicing wait time. Each simulator experience consisted of two 7-minute interactive sessions in a classroom with five virtual avatars with a ten minute break for feedback and reflection in between. GTAs were also expected to watch at least one of their peer's sessions to get more familiar with different implementations of the strategies. After the sessions, GTAs were prompted to explain how they were going to use the techniques they practiced in their own classes.

Research on Faculty

Selection

MATH-GAINS faculty participants were selected according to three main criteria. First, it was important to have faculty representing various ranks. Over the course of the study, there was one Professor, one Associate Professor, one Assistant Professor, one Lecturer, one Associate Instructor, and one Instructor. Second, the faculty participants needed to have interest and potential to truly implement evidence-based practices, which they had not used in their courses previously. Third, it was important to select faculty that had potential to influence other faculty and/or department policy. To this end, the faculty participants possessed at least one of the following characteristics:

- Taught calculus courses regularly
- Served as course coordinator for Calculus II or III

- Chaired or served on committees that effect course changes
- Displayed prior participation in education related grants or research
- Held the rank of tenure, which may indicate an influential voice with other mathematics researchers in the department.

In year one, there was one female and two male faculty with ranks of instructor, associate instructor and professor. All three participants in year two were female with ranks of lecturer, assistant professor and associate professor.

Training

Research (Henderson, Beach & Finkelstein, 2011) shows that short workshops do not facilitate institutional change. Instead, prolonged, consistent, intervention with reflection incorporated into the process leads to systemic change. MATH-GAINS was a one-year cognitive apprenticeship embedded within a vertical learning community of faculty and GTAs where faculty had the autonomy to select for themselves and implement on their terms evidence-based practice(s) in the Calculus classroom. Motivation theory suggests that providing autonomy for teachers leads to better outcomes for students (Roth, Assor, Kanat-Maymon & Kaplan, 2007).

Teams consisting of three faculty (one for each course – Calculus 1, 2 and 3) and five GTAs comprised the Learning Community (LC) for each year. Faculty LCs were designed to be a forum for exchange of information regarding evidence-based teaching strategies and the environment that nurtures support for the implementation of these practices. MATH-GAINS participants focused on developing mathematical understanding utilizing strategies centered on active engagement, effective use of technology and classroom assessment techniques. Faculty selected from a menu of evidence-based practices and developed learning materials that incorporated these practices in math courses over a two-semester period.

The totality of the professional development experience is summarized here, chronologically, and captured more succinctly in Table 2.

1. Faculty LC participated in a summer workshop, led by a faculty member from the Faculty Center for Teaching and Learning (FCTL) whose background was in chemistry. Programming included an introduction to STEM education research and the theories guiding effective practice. Through this context, the menu of MATH-GAINS' evidence based practices was introduced
2. Throughout the summer, the faculty LC participants brainstormed, discussed, reflected and developed curriculum and materials for their upcoming courses
3. Projects were implemented in fall semester and, through direct observations by trained mentors, the LC participants received formative feedback. LC faculty also visited each other's classes for support
4. GTAs made use of the teaching simulator once each semester
5. LC participants met monthly to debrief on their project, seek group support, and share ideas for success
6. LC participants attended a one-day winter workshop to discuss common experiences and "tweak" the evidence- based practices for the spring semester
7. Adjusted projects were implemented in the spring semester and underwent

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formative observations and summative assessments

8. LC participants disseminated lessons-learned, best practices and materials developed to a faculty audience at the university's summer faculty development conference. Findings were also shared with populations in the math department including the Year Two MATH-GAINS LC cohort
9. The cycle continued in the second year

Faculty and GTA teaching efficacy and beliefs were measured at the beginning and end of the year.

Measures

A variety of evidence was used to measure the effect that the professional development had on the instructors. Each faculty member was observed by an external observer who used the Reformed Teaching Observation Protocol (RTOP) to document the extent to which their lessons were reformed (according to the national science and mathematics standards for K-20 classrooms). Observations pre, during, and at the end of the faculty's participation in the program were analyzed. Faculty generated implementation plans, reflections and exit interviews were used to gain a better understanding of what the faculty were trying to do in their classroom and where they felt they had barriers. Researchers also surveyed all math faculty using the Culture, Cognition, and Evaluation of STEM Higher Education Reform questionnaire (CCHER; Hora, 2011) to ascertain faculty members' degree of acceptance of active learning classrooms. Two additional measures help provide insight into MATH-GAINS' faculty's beliefs about what constitutes good instruction in calculus (Calculus Teaching Scenarios; modified from Gill, Ashton & Algina, 2014), and their confidence in teaching calculus effectively (Calculus Teaching Efficacy Scales, modified from Gill, Ashton & Algina, 2014).

Table 2. MATH-GAINS training timeline by activity and participant type

Training Component	Training Category	Term			Participant	
		Su	Fa	Sp	Fac	GTA
Training Workshops	Professional development	X			X	X
TeachLive simulator	Support & feedback		X	X		X
Winter meeting	Professional development		X		X	X
Observation & mentor meeting	Support & feedback		X	X	X	
Monthly meetings	Professional development		X	X	X	X
Implementation (initial)	Intervention		X		X	X
Implementation (revised)	Intervention			X	X	X
Faculty conference	Sharing experience	X			X	

Outcomes

Based on Roth, Assor, Kanat-Maymon & Kaplan (2007), autonomy in letting the faculty member decide which strategies to use and how they were going to use them was a large part of the project's theoretical framework. Because of this, the implementation for each faculty member varied. One faculty member, for example, decided to include an active learning activity, suited to the day's objectives, into every lesson taught. Another faculty member mostly focused on modifying the discussions sections of the course led by GTAs. In this case, the faculty member designed student-centered lesson plans and assisted in mentoring the GTAs to lead an active discussion section once a week. Still another faculty member decided to flip the course and use the majority of face-to-face time for active student-centered learning.

When looking at efficacy and attitudes, analyses showed that faculty held more positive views of reform instruction (using evidence-based practices), and more negative views of traditional instruction following the intervention in Year One. RTOP analyses revealed that changes in instructor practice varied across instructors. One instructor showed a strong change in practice, which continued across the second year of the study. Multiple faculty showed moderate change in practice continued across the second year. It should be noted that there were a couple of faculty whose practice did not show noticeable change despite a change in efficacy and attitudes. Further investigation into factors that indicate readiness of faculty to change is warranted.

The TeachLivE simulator data of the GTAs is still being analyzed. Interview data with the GTAs indicates they thought that the avatars responded similarly to the way their students responded in class. They felt like the simulator helped them learn how to work with small groups of students, particularly when trying to lead students through a series of questions as opposed to direct instruction. The GTAs also felt that a limitation of the technology was that they did not feel like the practices they focused on would scale up to their larger classes. Most of the GTAs expressed difficulty in translating the skills they practiced in the simulator to their actual classes.

Research on results of the faculty interviews and beliefs measures is ongoing. One presentation has resulted from early analyses to date (Gill, James, Saitta, Moore, Dagley, Philps & Chini, 2017, August).

Research on Students

Selection

Student participation within the MATH-GAINS (MG) project included enrollment in one of the designated calculus sequence sections in the fall or spring over the two year project period, Fall 2015 to Spring 2017. As previously indicated, the calculus courses contained no specific designation that would assist students in identifying which sections were included in the project. This allowed registration for the courses to be random. All students meeting the appropriate prerequisites for the calculus sequence had an equal opportunity to register for a project course. Calculus 1 was random enrollment each term. Once a student participated in a MG course, he/she was invited to continue into the next MG course in the calculus sequence if they desired. This was allowed until the course reached capacity or the end of the primary registration period. Once current MG participants were registered, the remaining seats in the section were opened to the general population. For example, in MATH- GAINS' first semester, Fall 2015, all participants in the project randomly enrolled into the MG sections on their own. Before registration opened for Spring 2016, a member of the research team visited each MG section and invited the current students to register for the MG section

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of the next course in the sequence (i.e., Calculus 1 invited to enroll in Calculus 2). Those who expressed an interest were enrolled in the MG section of the appropriate course for spring. The same thing occurred each fall and spring term until the end of the project. This meant that some students enrolled in all three calculus courses with MATH- GAINS, some only enrolled in one and others chose to enroll in two courses.

Opening the remaining seats to the general population provided a comparison group built within each class. Future analyses will use this group to compare learning differences between those students who took multiple classes and those who experienced only one of the MG courses and to investigate any cumulative effect of experiencing multiple sections in an active learning environment. One potential factor that must be considered is whether academic differences in students in the comparison group affected outcome results. Students who register later for classes may be unsure of their performance in the class or future in a major, and thus differ significantly from early registrants. For this reason, a comparison holding constant for past academic performance or standardized test scores may be necessary to ensure there is no bias.

Coding

In order to be able to assess the MATH-GAINS effort, researchers had to appropriately define the cohorts for each course, term and year of the project. Once determined, each student enrolled in MATH-GAINS courses was coded in the university database using one of these definitions. Using only four characters as allowed by the parameters of the database, researchers determined ME## would be the best format. The first character "M" was chosen to designate the project "M"ATH- GAINS. The second character "E" represented the experimental group. This was important for future studies when specific control groups would be established and could use the designation of "C". The third character and first number corresponded to the number of the course in the calculus sequence: 1 = Calculus 1, 2 = Calculus 2 and 3 = Calculus 3. The final character and second number corresponded to the term in chronological sequence of the project. For example, Fall 2015 was designated as 1 for term one of the project, Spring 2016 designated as 2 for term two of the project, Fall 2016 as 3 and so on. Table 3 includes each of the term definitions.

The comparison groups used for analysis in the ongoing studies related to this project were composed of all other non- Honors and non-Learning Community sections of Calculus 1, 2 and 3 offered during fall and spring terms during the same period, Fall 2015 – Spring 2017.

Table 3. MATH-GAINS coding definitions

Code	Coding Definition
ME11	Experimental group Calculus 1 in term 1
ME21	Experimental group Calculus 2 in term 1
ME31	Experimental group Calculus 3 in term 1
ME12	Experimental group Calculus 1 in term 2
ME22	Experimental group Calculus 2 in term 2
ME23	Experimental group Calculus 3 in term 2
ME13	Experimental group Calculus 1 in term 3
ME23	Experimental group Calculus 2 in term 3
ME33	Experimental group Calculus 3 in term 3
ME14	Experimental group Calculus 1 in term 4
ME24	Experimental group Calculus 2 in term 4
ME24	Experimental group Calculus 3 in term 4

Demographics

Of the 1,908 students who enrolled in a MATH-GAINS course, 17 were eliminated because of admission in a graduate non-degree seeking category. Another 237 were removed from any analysis due to previous participation in a STEM learning community. Of the 1,654 eligible students the vast majority (n=1,329) were enrolled in Calculus 1 with the remaining 163 and 162 students enrolled in Calculus 2 and Calculus 3, respectively. The comparison group consisted of 4,528 students of which 1,456 were enrolled in Calculus 1 with the remaining 1,573 and 1,499 enrolled in Calculus 2 and Calculus 3, respectively.

Other demographic characteristics considered in the study included admission status to the institution, socioeconomic standing during the semester completing the course, gender, ethnicity and classification as a first-generation college attendee. The characteristic details for the MATH-GAINS participants and comparison groups are shown in Table 4.

Outcomes

Course Performance

Overall, there was no statistically significant difference in student performance based on DFW rates – those not successfully completing the course by failure or withdrawal – when comparing those students participating in MATH-GAINS courses and those in the general population courses (comparison group). In general, students in MATH- GAINS sections of Calculus 1 offered in fall had lower DFW rates than the comparison group, but the comparison group outperformed MATH-GAINS students in spring sections. For Calculus 2, the comparison group outperformed MATH-GAINS in every term. Just the opposite, MATH-GAINS students outperformed the comparison group in Calculus 3 in all terms except one where performance was almost identical. Deeper analysis is necessary to determine the reasons behind these differences including individual review by section each term to hold constant for instructor.

Table 4. Demographic characteristics of MATH-GAINS and comparison group students

Variable	MATH-GAINS	Comparison
First Generation	368	954
Low Income	391	1,068
First-Time in College Admit	1,169	2,995
Transfer Admit	433	1,419
Second or Non-Degree Admit	52	114
Female	523	1,072
Male	1,131	3,456
African American	150	338
Hispanic	442	1,136
White	781	2,331
Other or non-specified	281	723

First-time-in-college and transfer student admits in MATH- GAINS had about the same DFW rates, 41% and 42% respectively. However, when analyzed alongside the comparison group, first-time-in-college students performed much better (DFW for MATH-GAINS 41% vs. Comparison 37%) in the general population courses while transfer students performed much better (DFW for MATH-GAINS 42% vs. Comparison 56%) in the MATH-GAINS courses. This could be attributed to the academic maturity of transfer students, having experience in college level courses and leading to the ability to adapt to different types of instructional methodologies whereas, first-time-in-college students may be accustomed to a more traditional style of lecture and are still acclimating to college level rigor. There was no significant difference in performance based on gender though both males and females had slightly lower DFW rates in the general population courses. When looking at ethnicity, African- American students had lower DFW rates in MATH-GAINS while Caucasian students had lower DFW rates in the general population sections, but there were only slight differences for each group. The most significant differences were for Hispanic students who had lower DFW rates in the general population courses compared to MATH-GAINS, 42% and 51% respectively.

A few factors impacted this portion of the student analysis. Limitations include, but may not be limited to:

1. The use of grades in courses which are known to be a less effective and more subjective variable for comparison.
2. Students repeating a course were included in the total counts therefore, student counts were not uniquely identified. Additionally, a poor performing student in one class could be expected to be poor performing in subsequent attempts of the course.
3. Most MATH-GAINS sections contain late enrolled students. Late enrollment occurs when a student postpones registration which is often due to indecision on continuing with a major or expected or actual poor performance in a class. This could mean that a larger percentage of students with a poor performance record enrolled in MATH-GAINS sections.

When looking at only MATH-GAINS participants, 91 students took at least two courses in the calculus sequence with the program. Of this group, 56 passed (61%) and 35 failed (39%) the second course. Only 7 students took all three courses in the sequence with MATH-GAINS. For those with low performance in a MATH-GAINS course, 96 repeated a course in the sequence with MATH-GAINS. Of this group, 37 failed (39%) the second attempt and 59 passed (61%). The number of students taking additional courses in the sequence or repeating courses with the project was limited for two reasons: (1) because MATH-GAINS offered large lecture Calculus 1, but only one section each of small lecture Calculus 2 and 3 only approximately 100 students could move forward each semester and (2) by the time students found out they needed to repeat a course the majority of the MATH-GAINS seats were filled, eliminating the opportunity for many to repeat with the program.

Persistence

One student outcome associated with the project related to persistence of students in a STEM major. The outcome was divided into two measures, persistence in and graduation from the STEM major. Initial analysis combined the two measures for a single retention rate. Preliminary results were positive.

Because students enrolled in MATH-GAINS courses were not from a single entering cohort (i.e., students enrolled were admitted in many different terms and years), a traditional fall- to-fall retention calculation would not accurately reflect retention in STEM as defined by the project. Instead, MATH-GAINS STEM retention was determined by taking all students enrolled in a MATH-GAINS section, reviewing their major upon admission to the institution (STEM vs. non-STEM) and conducting two-year or one-year term-to-term (i.e., fall MATH-GAINS enrollment to fall one and two years out, spring MATH-GAINS enrollment to spring one and two years out) persistence or graduation in STEM. The comparison group for this outcome was the All STEM population inclusive of both first-time-in-college and transfer students. All calculus courses offered in the MATH-GAINS' sequence boasted higher two-year and one-year retention rates in STEM than the All STEM population. Table 5 outlines the one and two-year retention (persistence and graduation) rates for each MATH-GAINS calculus course and the All STEM population.

When examining MATH-GAINS' participants, there were a number of trends that one would expect to see.

1. There was a higher percentage of STEM majors as a total of enrollment in Calculus 2 and 3 than in Calculus 1. This can be credited to actual volume of students in Calculus 1 or that it is the first course in sequence and many students enroll with limited intentions of moving forward in STEM (i.e., students who change a major during the first term of enrollment).
2. One-year and two-year retention rates in Calculus 2 and 3 were significantly higher than Calculus 1 in most terms. By the time students reach these courses, they are further along in their STEM major with more time invested. The majority of students choosing to leave the STEM major early on typically do so after the initial gateway course.
3. Persistence in the STEM major was higher one year out than two years out as shown in Table 4. Retention research (Braxton, Brier & Steele, 2008) shows that though the majority of students who leave do so in the first year, a similar percentage exit during year two. A large percentage attempt to persevere beyond the first gateway course, but make the decision to leave when not performing well during the second or third course in the sequence before investing too much time.

Table 5. One and Two-Year Retention Rates for MATH-GAINS and the All STEM Population

Year	MATH-GAINS			All STEM
	Calculus 1 (%)	Calculus 2 (%)	Calculus 3 (%)	(%)
Two-Year	63	76	76	57
One-Year	74	81	86	69

Continued review of the data is warranted. Future analysis will include break downs of retention by gender, ethnicity and even individual STEM majors.

Sustainability

The purpose of this study was to examine faculty change and its impact on students, as the teacher change literature often does not directly connect changes in

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teachers' knowledge, professional development or behaviors with student practice (Buehl & Beck, 2015). Thus, we began with the analyses on student data. Though student data shows initial positive results, it was the research with and development of the faculty that were the primary focus of this project. Advancing student success would not be possible without sustaining the faculty development component. The goal set forth by MATH-GAINS was to create an ecosystem where an influential number of the Department of Mathematics faculty at a large metropolitan university persistently and sustainably applied evidence-based practices in their teaching of Calculus courses. As evaluation of the year two faculty data continues, the researchers believe the project has been very successful in moving faculty towards the use of evidenced-based practices.

Over the course of two years, which was the MATH-GAINS project duration, the Department of Mathematics made many significant changes, each one influenced to some degree by MATH-GAINS. Three of these changes were initiated and accomplished by the principle investigator of MATH-GAINS. First, a regular (semi-weekly) math education seminar series was organized. The seminars showcase teaching practices and results from faculty both inside and outside the department, promoting regular exchange of ideas, and typically boast higher attendance than other regular mathematics research seminars in the department. Second, one mathematics colloquium is devoted to mathematics education each year. These colloquia are generally given by experts from outside the university, and are attended by most of the department. Third, the department hired a tenured professor who has secondary research interests in math education and a tenure-track faculty member, whose primary research interest is math education. As there are no other faculty in the department with the same primary research focus, this denotes a significant change, which is necessarily reshaping the role of mathematics education research within the department.

In addition, further changes in the department have resulted from the actions of faculty that participated in the MATH-GAINS program. To be specific, four MATH-GAINS faculty participants serve on the department's Calculus Committee; one of the four is serving as the committee chair. The committee continues to gather and analyze data in order to better understand failure rates, and they are actively pursuing bold changes to course design, materials and curriculum. Finally, a new Mathematics Education Committee has been created to assess, promote and implement further developments, now that the MATH-GAINS program has officially ended. Though much analysis remains, researchers are encouraged by the progress of cultural change initiated within the Department of Mathematics at all levels of the faculty ranks.

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