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Investigation of Mastery Math Lab Impact on Undergraduate College Algebra Student Success

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Abstract

Student success in introductory mathematics courses has been a topic of national concern due to the high failure rates associated with these courses and the impact on STEM degree retention and completion. At Florida International University (FIU), College Algebra underwent an extensive reform in 2012 leading to the implementation of the Mastery Math Lab (MML). Within this lab, students engage in a student-centered active-learning mathematics environment where they can work through problems at their own pace while receiving immediate feedback from faculty, peers, and Learning Assistants. This study aims to determine the impact of the Mastery Math Lab on student performance, by analyzing student data (i.e., pre- and post-implementation). Results show a significant upward trend in the percentage of students passing the course after implementation, as well as a significant increase in the average course grade, with consistent improvements. Analysis of student perception survey responses suggest that students perceive Mastery Math Lab as beneficial for their success in College Algebra and the integration of undergraduate Learning Assistants (LAs) to be conducive to their learning.

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Introduction

There is a high demand for the development of a robust Science, Technology, Engineering, and Math (STEM) workforce to support improved living standards, national economic growth, global competitiveness, and economic mobility (NSF, 2021). The shortage of a STEM skilled workforce is fueled by fewer students completing degrees in core STEM fields (Glennie et al., 2019). While the exact definition of STEM skills is still in question (Black et al., 2021; Siekmann & Korbel, 2016; Suárez-Carreño, 2023), they are generally regarded as literacy and numeracy skills within the fields of science, computing, engineering, technology, and mathematics (Suárez-Carreño, 2023; Walker & Zhu, 2013). The demand is so high that the US workforce expects it will suffer a shortage of approximately one million STEM graduates if students continue to graduate at the same rate (Bradford, 2023; Olson & Riordan, 2012; Hodges & Kim, 2013; Rifandi et al., 2019). As it stands, only 40% of students who begin their college education as a STEM major end up graduating, due to students switching out of STEM majors before getting the chance to graduate as well as a decreasing interest in pursuing STEM (Bleemer, 2024; Hodges & Kim, 2013; Ismail & Yusof, 2023). To address this shortage, graduation rates of STEM students would need to increase by 34%. There has been much discussion on how to increase retention of students in STEM majors, including the improvement of student attitudes towards mathematics (Eronen & Kärnä, 2018; Hodges & Kim, 2013). Improving students' attitudes towards mathematics could facilitate retention rates, as decades of research have shown a strong association between student attitudes towards mathematics and their success and efforts in mathematics courses (Aiken, 1976; Hemmings & Kay, 2010; Hodges & Kim, 2013; Ma & Kishor, 1997; Neale, 1969).

The implementation of diverse learning activities in the classroom has been shown to increase the retention and graduation rates amongst STEM undergraduate students (Gates & Mirkin, 2012; Graham et al., 2013). Institutional implementations such as blended learning have had similar effects in STEM contexts, providing flexibility in how students regulate and direct their own learning behaviors (Nguyen, 2019; Stitts, 2022; Evenhouse, et al., 2023). These approaches, supported by previous studies in mathematics and other disciplines (Fuller et al., 2016; Eronen & Kärnä, 2018; Deshler et al., 2019; Miller et al., 2021), play a pivotal role in ensuring students' success and retention in these courses.

Traditionally, however, mathematics instruction has leaned towards an instructor-centered approach, often overlooking strong evidence that student-centered approaches improve student learning and attitudinal outcomes (Freeman et al., 2014; Kramer et al., 2023). By using student-centered activities in STEM courses, such as structured small group discussions and frequent formative feedback, introductory-level mathematics courses have improved student engagement and success (Borda et al., 2020), including increased sense of belonging and improved faculty-student interactions. Enhanced by student-centered methodologies, the landscape of learning mathematics can transform to actively encourage student collaboration, promote agency, and facilitate self-paced learning.

Within introductory mathematics courses, due to low retention rate of students in these classes, educators are seeking ways to improve student performance through redesign methods (Cousins-Cooper, et. al, 2017). These courses have the highest need for redesign due to traditionally high failure rates, larger enrollments, students with inconsistent preparation levels, or a combination of these factors (Bonham & Boylan, 2011). Redesign models that cater towards mathematics introductory courses typically have similar innovations implemented that include the efforts to accelerate remedial courses, adjust the curriculum, or offer corequisite support alongside these college-level courses (Boatman, 2021).

Students that have additional support during the course, such as a required recitation section or laboratory, are more likely to experience long–term academic success (Jones, 2015). These redesign models in mathematics promote student-centered approaches that actively engage students with their peers to expand their own thinking (Bishop & Verleger, 2013: Borda et al., 2020). Thus, rethinking the way instruction is delivered to create mathematics classrooms that center around a student focus has a high likelihood of leading to better learning outcomes (Twigg, 2011).

Institutional Context and Mastery Math Lab

Mathematics courses, often beginning at the College Algebra level, are almost always needed to graduate college with a bachelor's degree (Guillergan & Vencer, 2004). In particular, College Algebra has been noted as a course where students failed more often than any other introductory-level course (Herriot & Dunbar, 2009). The Mastery Math Lab (MML) space at Florida International University (FIU) was built in 2012 to provide a student-centered environment designed to help students engage meaningfully with mathematics in their courses. College Algebra (course code MAC 1105) was specifically chosen for this research study due to it being a "high-risk" course, defined as any course which has large enrollment where 30% of students either withdraw from the course or earn a D or F as their final grade (Bambara, et. al, 2009).

At FIU alone, about 3,500 students enroll in College Algebra each school year (Merkin, 2023), thus making it a key course for student retention and graduation. To maximize students' access to the MML, the hours of operation are aligned with the needs of the institution's student population, including evening and weekend hours. This concept is influenced by the Mathematics Emporium Model, where students are encouraged to work through problems on the computer with immediate and personalized feedback from faculty, resulting in mastery of content (Merkin, 2023; Twigg, 2011). Students who used the Math Emporium electronic resource at Virginia Tech, Kings Community College, University of Alabama, University of Idaho-Moscow, and University of Missouri-St. Louis performed better on exams, retained more knowledge, and were more successful when answering open-ended questions (Guerrero et al., 2020).

Student-centered learning has the potential to play a major role within the Mastery Math Lab model, creating an environment where students are engaged with course material as well as other students and peer Learning Assistants. Students in courses paired with the MML at FIU are required to spend one and a half to three hours a week in the lab completing homework, while receiving feedback from faculty and Learning Assistants (Merkin, 2023). This required time allocation supports a "High-Tech/High-Touch" approach that increases student engagement, success, and retention (Lahcen et al., 2019; Merkin, 2023; Webel & McManus, 2017). It combines an increased use of technology and human support structures to improve students' perceptions of learning and understanding of their course work while simultaneously strengthening their foundational concepts and skills (Braxton et al., 2000; Edmunds et al, 2021; Green, 1999).

Students in the MML are encouraged to work together on structured activities where they critically solve complex math questions within the lab, form relationships with each other, and build on their mathematics skills inside and outside the required lab hours. By fostering collaboration with peers on activities such as reviewing class notes or solving questions, this student-centered approach increases student self-esteem, promotes critical thinking skills, and actively engages students in the learning process (Gopinathan et al., 2022). This deliberate use of active learning, implemented through step-by-step instruction, guidance, and discussions, results in reinforcement and clarification of material, long-term retention, and overall better student course performance (Allsop et al., 2020).

In addition to interacting with faculty, the MML provides a space for students to receive assistance and support by connecting to undergraduate peer mentors (i.e., Learning Assistants) (Twigg, 2011). Learning Assistants (LAs) are undergraduate students that have disciplinary and pedagogical knowledge of the course assigned to them, which allows them to successfully facilitate cooperative learning among the students (Barrasso & Spilios, 2021). The LA model provides peer instruction through evidence-based practices that include development of LAs through three key components:

(1) a semester-long pedagogy course to learn about the science and practice of teaching and learning;

(2) weekly preparatory meetings with faculty to discuss course content, student understanding, and provide feedback to instructors on the student perspective; and

(3) the actual practice of supporting implementation of learning-centered teaching practices (Barrasso & Spilios, 2021; Biswas, 2022; Hower et al., 2023; Top & Otero, 2018).

In the MML, LAs facilitate learning by providing immediate feedback and support to students on their questions on homework or related content (Twigg, 2011). LAs also engage with students on non-course related areas by providing near-peer mentorship on academic and non-academic issues that may impact student success (e.g., study skills, time management tips, institutional resources, career advice) (Price et al., 2019).

In this study, we use student success measures from before and after the opening of the Mastery Math Lab (MML) to determine the impact that the MML has had on student performance and success, specifically in College Algebra. Our goal is to understand the impact of MML on College Algebra students – including their academic success and their perceptions of introductory mathematics courses. We aim to contribute to the emerging literature on the Math Emporium model to inform the redesigning of College Algebra to include student-centered and scalable approaches in post-secondary institutions.

Materials and Methods

We evaluated the impact of the Mastery Math Lab (MML) through a quantitative approach. The data for our study came from various sources, including surveys collected from students that are currently enrolled in College Algebra, as well as course-level student data in College Algebra. We obtained Institutional Review Board approval from Florida International University to conduct this study (#22-0428). Please note, this study's data was collected at a single university.

Student Quantitative Data Analysis

To investigate the impact on student performance, we accessed College Algebra institutional student data from fall and spring semesters starting in Fall 2011 to Spring 2022. This data set includes historical data before the MML was implemented (i.e., before Fall 2012 for main campus sections and before Fall 2018 for sections in a secondary campus). Note that all in-person College Algebra sections after Fall 2018 had a MML requirement as part of the students' grade, thus only semesters before 2018 included a portion of the sections without MML. We excluded data from semesters when teaching was impacted by the Covid-19 pandemic (i.e., Spring 2020, Fall 2020, Spring 2021). We also excluded students taking fully online courses and dual enrollment students. The data file included 20,817 observations with 17,800 unique students.

The data set included the following variables: MML status (whether a student was taking a Mastery Math Lab supported course or not); STEM major status (37% of students declared as STEM majors); Honor's College status (1.4% were active Honor's College students); International Student status (4.4% with F1 student visas); FTIC students (77% of students who have enrolled in a post-secondary institution for the first time); sex (53% male students and 46% female students); Hispanic identity (67% of students with Hispanic ethnicity); Black/African American identity (14.7% of students identify as Black/African American, as their primary race); Pell recipient status (40% of students were eligible to receive Pell Grants); High School GPA (average 3.62/4.0, ± 0.45 SD, 5% missing data).

Student Grade Point Unit (i.e., the numerical course grade in a 4.0 scale, GPU) was used as the indicator of student performance (i.e., outcome variable). The numerical values of letter grades are as follows: A (4.0), A- (3.67), B+ (3.33), B (3.0), B- (2.67), C+ (2.33), C (2.0), C- (1.67), D (1.0), F and DR (0). Only student data points with grades that impacted the GPA were included. We used institutional data to acquire the original instructor's final grade for students that received an NC (students that received a D or F and got no credit for their course, due to a grade forgiveness program). Descriptive analysis of the data included calculating the percentage of students passing and failing the course across semesters and across MML status (i.e., with and without Mastery Math Lab) as well as the percentage letter grade distribution.

We employed a multiple regression analysis, using GPU as the outcome variable. The treatment was defined as any College Algebra course that was reformed through the support of the MML, which included faculty and undergraduate Learning Assistants providing student support in real time. In the linear regression model, variables were included to control for previous student academic performance (high-school GPA, Honor's College status), academic context (STEM major status, transfer status, international student status), and demographics (sex, race/ethnicity minority status, Pell eligibility). These variables were selected because they have been reported to be common predictors of student course performance, attributed to systemic and structural biases experienced by those groups (Biswas et al 2022; Sax et. al, 2016; Westrick et al., 2015, Allensworth & Clark, 2020; Eddy & Brownell, 2016; Lakin & Elliott, 2016). Throughout these analyses, we set alpha, the maximum acceptable chance of Type I error, to 1%. One limitation of this analysis is that it is using academic performance (i.e. final course grade) as the sole outcome of student success and may miss other important student measures, such as socio-cognitive outcomes. Analyses were performed in R (R Core Team, 2017), the open-source programming and software environment for statistical computing and graphics, including the following packages: base, dplyr, reshape2, ddply, and ggplot2.

Student Perceptions Survey Data Set and Analysis

Currently enrolled College Algebra students who had an MML requirement in their class completed a voluntary online survey at the end of the semester. The survey included items investigating student perception of the MML program and its elements, including personnel support (e.g., LAs) and community engagement (e.g., support from other students). The survey was administered during the following semesters: Fall 2018, Fall 2019, Spring 2020, and Spring 2022; and had the following student sample sizes: 1789, 1058, 441, and 265, respectively. The data set included counts of students responding to survey items and disaggregated by semester.

In line with the quantitative data set chosen above, we excluded data from semesters that were fully online, or modified instruction formats (i.e. FIU online-live courses) due to the Covid-19 pandemic (i.e., Fall 2020, Spring 2021, Spring 2021). Students were asked to indicate their experiences with the MML related to its overall impact on their course success along with their experiences with undergraduate Learning Assistants. Student responses were on a 4-point Likert scale specific to the item. To analyze the data, we averaged the percent of students selecting a particular response across all semesters in the data set One limitation of this analysis is that it is based on self-reported student perception data and may not correlate with individual student academic outcomes.

Results

Course Data Analysis

To determine the impact of FIU's Mastery Math Lab (MML) on student performance, we analyzed the final letter grades received by College Algebra students. First, we compared the passing and failing rates of College Algebra students from Fall 2012-Spring 2022, excluding Spring 2020, Fall 2020, and Spring 2021. Students categorized as "passing" were students who finished the course with a C grade or higher (i.e., A, A-, B+, B, B-, C+, and C). Students who finished the course with a C- or below (i.e., C-, D, F) were considered non-passing, i.e., they failed the course and would have to retake it. Students who withdrew or dropped out of the course (e.g., DR grade) were also considered non-passing students.

Figure 1 shows an increasing passing rate across time, starting from 40% of students passing the course before MML was implemented (Fall 2011 and Spring 2012) and increasing to around 60-70% passing after the implementation of MML. In the year after the inauguration of the MML, the passing rates increased by 10 percentage points from 40% to 50%. From Spring 2014 to the Spring of 2022, the implementation of the MML resulted in even greater passing rates for College Algebra students, reaching passing rates of above 70% in Fall 2018, Fall 2019, and Fall 2021 (see Figure 1).

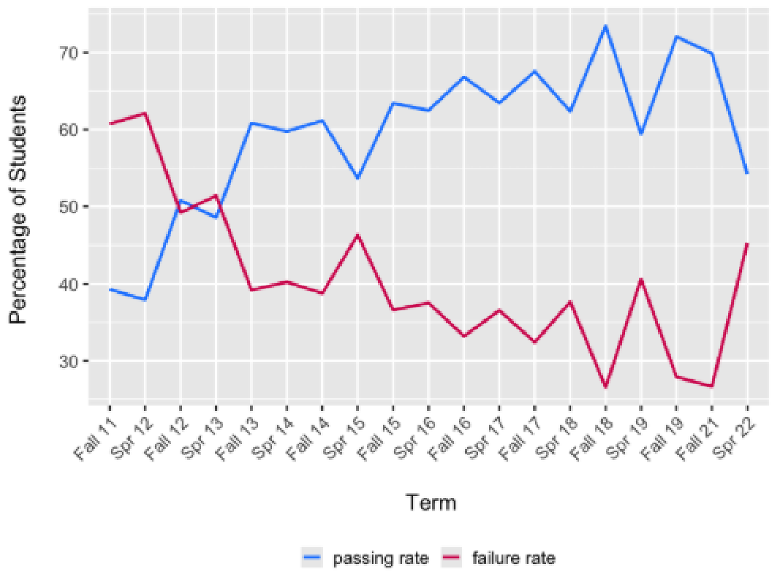

Figure 1. The Percentage of Students Passing/Failing College Algebra from Fall 2011 to Spring 2022 Semesters *[The blue line represents the percentage of college students that finished the course with an "C" or above letter grade (i.e., passing grade). The red line represents the percentage of college algebra students that finished the course with a "C-" or below letter grade (i.e., failing grade), NC grades, students who dropped the course after the drop deadline (DR), and students who withdrew from the class (WI) are considered Fs. The number of students per term varied from 2,467 (max) to 664 (min) with an average of 1,270 per semester.]*

Figure 2 depicts the percentage of College Algebra students that passed/failed the course, and the percentage of students awarded different letter grades, grouped by those that had a MML requirement and those that did not. Please note that after Fall 2012, all College Algebra sections on the main campus included a requirement for MML, and after Fall 2018, all College Algebra sections across the university (i.e., in satellite campuses) had implemented a requirement for MML as well. The overall passing rate before MML was implemented was 39.2% (with a 60.7% matching failure rate), while after implementation we observe an overall passing rate of 65% (with a matching failure rate of 35%) (see Figure 2a). Before MML implementation, in Spring 20212, the percentage of students receiving a grade letter "A" was about 5% and this result was accompanied by a failure rate of 25.6%. In comparison, after the inauguration of FIU's MML, the percentage of letter "A" grades received increased with an average of 19.8% and a maximum of 29.6% (in Fall 2018) (see Figure 2b). There was also an increase in passing students with a letter "B" grade moving from an average of 14.6% before MML to 22.7% after MML, with a maximum in Fall 2018 (25.3% of Bs) (see Figure 2).

Students' final course grades for College Algebra were assessed through a regression model that included the MML treatment as a predictor, as well as several control variables (see Table 1). Course grades were in a scale of 4.0 points with standard letter grades. MML treatment was defined as College Algebra sessions that required students to attend the MML, thus spending additional out-of-class time solving homework problems with support from instructors or undergraduate Learning Assistants. For comparison, institutional records of College Algebra students' performance in the course before the MML was implemented were used.

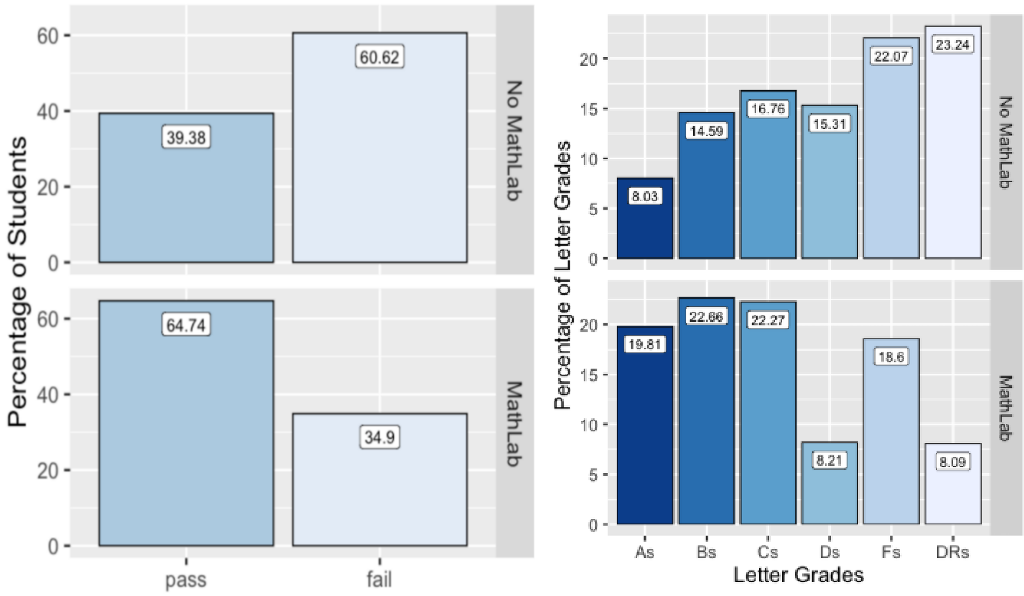

Figure 2. Course Performance of College Algebra Students without (0) and with (1) the FIU Mastery Math Lab Requirement

*[**(a).** Percentage of passing and failing grades received by College Algebra students. The bars represent the percentage of college algebra students that passed or failed the course. **(b).** Percentage of letter grades for College Algebra students. The bars represent the percentage of college algebra students that received a particular letter grade. From left to right, this bar graph reads "As" (A and A-), "Bs" (B+, B, B-), "Cs" (C+, C), "Ds" (C-, D), "Fs" (F), and DRs (drop after deadline).]*

The MML had a positive, statistically significant impact on students' course grades. We found that students that were supported through the MML demonstrated a statistically significant positive impact on student grade with students who attended the MML scoring 0.56 points higher (on a 4.0 maximum scale) than their peers who did not have the MML available as a resource ($p < 0.001$, medium effect size, $d = 0.59$). The control variables in the linear regression behaved as expected:

(1) High School Grade Point Average (GPA) had a statistically significant positive effect on course grades, as consistent with prior literature showing it as a consistent predictor of college performance (Han et al., 2020). On average, in this regression model, for every unit increase in high school GPA, students were predicted to increase their College Algebra grade by 1.03 points on the 4.0 scale.

(2) *Honor's College Status:* The linear model also considered whether students were part of the Honor's College, which had a statistically positive effect on their final College Algebra grade. This is consistent with these students having higher GPAs and SAT scores, which are needed for admittance into the program (Allensworth & Clark, 2020; Westrick et al., 2015).

(3) *International Student status* was also considered, since the institution has a significant number of International Students. The linear model showed a statistically significant and positive effect on the College Algebra final grade, with international students having an average difference of 0.75 grade points compared to their non-international counterparts (Katsumoto & Bowman, 2023).

(4) *Student demographics* that were included in the linear regression included student's sex and race and minority status. Female students and male students did not have any significant differences between their

performances. Similarly, there was no statistically significant difference (p>0.01) between the performance of Hispanic students and their non-Hispanic counterparts. The linear regression did show a small statistically significant negative effect for Black and African American students, consistent with literature pointing to the challenges faced by students of color in Hispanic Serving Institutions and Primarily White Institutions (Choi et al., 2023).

(5) *STEM major status* had a small statistically significant negative effect on GPU, with non-STEM students showing improved academic outcomes. This result may suggest unaccounted differences between STEM students who did not "test out" of College Algebra and non-STEM students required to fulfill a core curriculum requirement.

(6) *Pell Recipient* indicator demonstrated a statistically significant negative impact on final grade, -0.06 points on average, which is historically supported by the equity gaps for minority students (Bowman & Nelson, 2021).

Table 1. Regression Results of Mastery Math Lab Implementation on Student Course Grade Point Unit

*ns not significant (p>0.01), ** p<0.01, ***p<0.001*

Variables	Estimate	Std. error	p-adj
(Intercept)	-2.22	0.083	***
MML Implementation	0.56	0.025	***
Controls			
Student high-school GPA	1.03	0.021	***
Student Honor's College status	0.81	0.068	***
International Student status	0.75	0.048	***
Student transfer status	0.05	0.023	***
Student major (STEM)	-0.05	0.017	**
Student Hispanic identity	-0.04	0.025	ns
Student Black/AA identity	-0.12	0.032	***
Student sex (Male)	0.03	0.018	ns
Student Pell recipient status	-0.06	0.018	***

Student Perceptions of Mastery Math Lab Usefulness

Students that participated in courses which required Mastery Math Lab (MML) participation were invited to complete an anonymous survey about their experiences with the MML. We analyzed responses to six individual survey items; all rated in an item-specific 4-point Likert scale (see Appendix for Supplementary Table). College Algebra students were asked to rate "How much did the Math Lab help you succeed in the course?" On a 4-point Likert scale, students could rate their experiences (see Figure 3). On average, 40% of students stated that the MML helped them succeed *a lot* in the course, and 30% of students stated that it helped them *a moderate amount* in the course. Overall, over 70% of students reported that they were positively impacted by the MML in relation to their success in College Algebra.

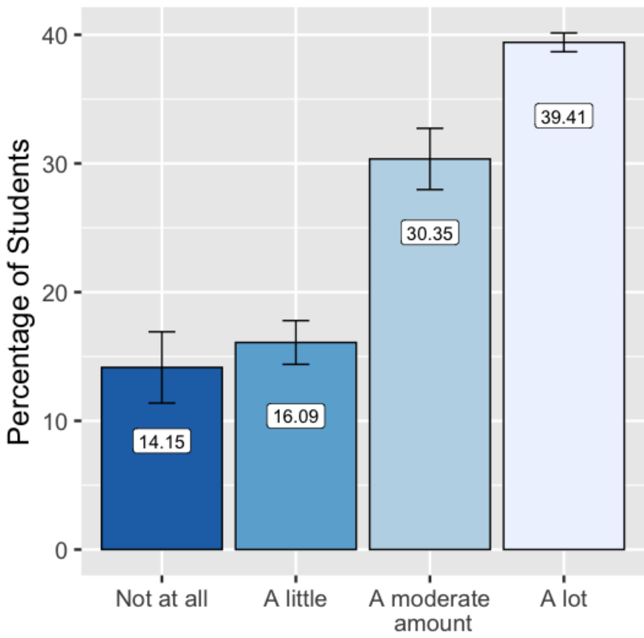

Figure 3. Student Perception of Mastery Math Lab Usefulness

[College Algebra students were asked in an end-of-semester survey "How much did the Math Lab help you succeed in this math course?" Students indicated their agreement in a 4-point categorical Likert scale (i.e., "Not at all", "A little", "A moderate amount", and "A lot"). There was a total of 3,553 student responses across 4 semesters, including Fall 2018 (n = 1789), Fall 2019 (n = 1058), Spring 2020 (n = 441), and Spring 2022 (n = 265). Bars indicate the average percentage of students selecting a particular response (across four semesters) and the whiskers indicate the standard deviation.]

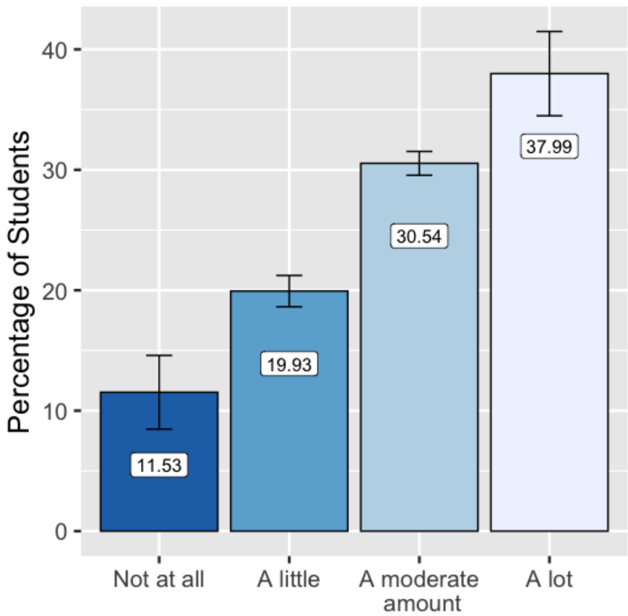

Figure 4a. Learning Assistant Impact on Student Success in College Algebra

[The survey question asked, "How much did the Learning Assistants help you succeed in the course?" and students responded through a four-option answer choice (i.e., "A lot", "A moderate amount", "A little", and "Not at all").]

College Algebra students were also asked about their opinions on the Learning Assistants based on the effectiveness of them being embedded into the MML (see Figure 4a). The question asked, "How much did the Learning Assistants help you succeed in the course?" (four-option answer choice included "A lot", "A moderate amount", "A little", and "Not at all"). On average, 38% of students stated that LAs helped them succeed in the course by "a lot", with an added 31% of students who on average said they help them a moderate amount. Thus, roughly 69% of students stated that they do see LAs being a helpful resource to succeeding in the course. About 30% of students perceived that their course success had little to no correlation with the LAs, with 20% of students stating they helped a little and 12% stating they did not help at all.

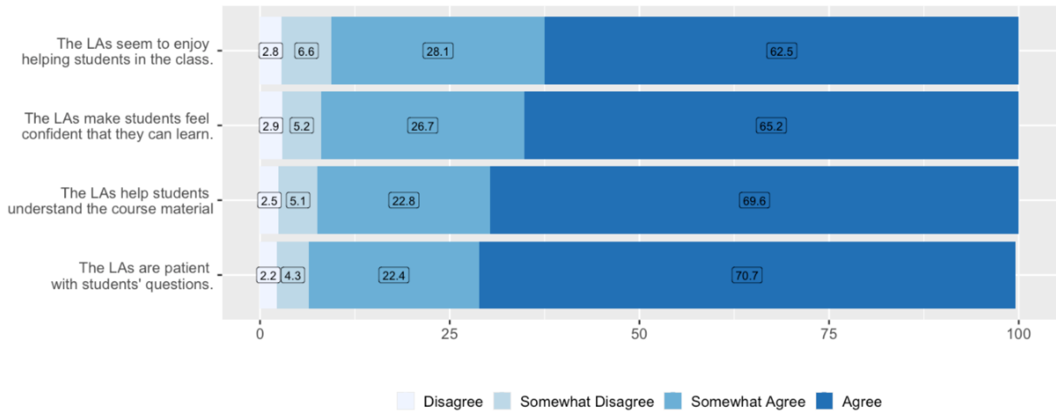

Figure 4b. Student Perception of Mastery Math Lab Learning Assistant Practices

[College Algebra students were asked in an end-of-semester survey, "Indicate how much you agree with the following statements about LAs." Students were given positive statements on LAs and were asked to indicate their agreement in a 4-point categorical Likert scale (i.e., "Agree", "Somewhat Agree", "Somewhat Disagree", and "Disagree"). There was a total of 3,521 student responses across 4 semesters, including Fall 2018 (n = 1779), Fall 2019 (n = 1051), Spring 2020 (n = 430), and Spring 2022 (n = 261). The x-axis indicates the average percentage of student responses across semesters. Stacked bars are colored by the Likert scale categories as shown in the figure legend.]

In the same survey, College Algebra students were also asked to respond to questions rating their perceptions of Learning Assistants within the MML (see Figure 4b). Students rated a set of four different statements relating to their experiences with LAs from a four-option scale (i.e., "Agree", "Somewhat Agree", "Somewhat Disagree", and "Disagree"). Overall, students rated their experience with Learning Assistants as a positive one, agreeing with LAs being patient and helpful. First, most student survey respondents (90% overall) perceived that LAs enjoy helping the students within the MML. About 62% agreed with the statement that the LAs enjoy helping students, with 28% of students selecting they "somewhat agree" to this statement. Second, most students (93%) agreed or somewhat agreed that LAs are patient with students' questions (i.e., "The LAs are patient with students' questions"), with only 7% of students somewhat disagreeing or disagreeing with this statement. Third, most students agreed with the statement "The LAs help students understand the course material", with 91% of students agreeing and somewhat agreeing with this statement. Finally, 92% of students agreed or somewhat agreed with the statement "The LAs make students feel confident that they can learn."

Discussion

The Mastery Math Lab (MML) provides an example of a course-specific effort sustained across several years to improve student success in College Algebra at a Hispanic Serving Institution. In our findings, we provide evidence that the MML has a positive and statistically significant impact on student academic performance, even after controlling for multiple demographics and academic background variables. The implementation of the MML has greatly increased success rates within College Algebra, leading to increases of over 20% percentage points in passing rates (i.e., from less than 40% to over 60% passing), improvements in the average Grade Point Unit (i.e., letter grade), and decreases in drop rates, which may imply that students have an increased perception of potential success. Additionally, student perceptions of the MML and its support are largely positive, with students stating that the MML helped them succeed in the course and rating Learning Assistants as having a positive impact on their learning. This supports research that shows that student perception and academic achievement have reciprocal influence, where student perception affects how they perform in class and academic performance impacts student self-perception in the course (Hagan et. al., 2020; Hodges & Kim, 2013).

Our study amplifies the idea of constructing environments where students can enhance their learning through different resources and grow their confidence to succeed in the course. Within the MML, students have a chance to perform College Algebra problems and enhance their skills at their own pace, improving their academic performance. The ability to receive immediate feedback and learn from mistakes can improve math skills and also overall perception of the class. Through progress monitoring by an interactive learning platform (i.e., Pearson MyMathLab) and in-person MML Learning Assistants and faculty, the MML can enhance student learning, connectedness, and student perceptions; similar to outcomes found in Math Emporium model (Young, 2015).

At FIU, the MML model also provides support through a high-tech/high-touch approach. By providing interactive technology (high tech) and facilitating a supportive community that caters to students' needs (high touch), this approach effectively motivates students and helps them succeed in these learning environments (Polka et al., 2014). These results are consistent with previous research done on the effectiveness of the Math Emporium model and an in-person supportive environment (Barrasso & Spilios, 2021; Boatman, 2021; Twigg, 2011; Wang, 2019; Williams S.P., 2016). The MML high-touch component relies on undergraduate Learning Assistants, which strengthens the student's connection with the course and fosters a supportive learning environment. Learning Assistants are used as peer mentors who promote student learning through student-centered and collaborative practices, leading to improvements in student performance, perceptions of the course, passing rates, and retention (Sellami et al., 2017). Results from prior research show that Learning Assistant programs enhance the effectiveness of active learning, improve student success, and close the achievement gaps among different demographic groups (Breland et al., 2023; Cao et. al., 2018; Sellami et al., 2017). Closing the achievement gap fosters inclusive and equitable education by providing resources for all students to succeed (Kotok, 2017; Li & Hazan, 2010; Moreu & Brauer, 2022; Williams A., 2011).

Supporting engaged student learning requires institutional support and resources. In the most recent semester of the MML, it served 3442 students (across College Algebra and other courses) and was supported by 58 Learning

Assistants, 25 faculty and staff; demonstrating that it is a scalable program. Although this model can be executed at scale, its elements can be implemented in varied combinations appropriate for different sized settings and institutional structures. For example, the MML provides a structure to help students stay on task and increase their time engaging with the material, which can be accomplished through recitation sections (Watt et al., 2014; Dasinger et al, 2019), allocating time-on-task in the classroom (Allsop et al., 2020), and smaller MML-like centers. These structures foster inclusion and develop a sense of community that leads to more student engagement and success (Borda et al., 2020; Gopinathan et al., 2022).

Similarly, one of our main findings from this study was the importance of LAs on improving student success in the course. While there are numerous institutional challenges to incorporating Learning Assistants into STEM courses, LAs have been successfully implemented in multiple contexts at other institutions (Sellami et al., 2017; Cao et al., 2018; Price et al, 2019; Barrasso & Spilios, 2021). Adopting an undergraduate LA program is an effective way to increase student engagement, retention, and satisfaction in a course (Groccia & Miller, 1996; Jardine et al., 2020; Knight et al., 2015; Pivkina, 2016; Talbot et al., 2015). The Learning Assistant Model can be implemented in ways that address institutions' unique needs, as it can be integrated into different course contexts and scales, thus, maximizing the benefits of the implementation of the LA model while adhering to budget constraints.

Conclusion

Succeeding in introductory mathematics courses is crucial to determining student recruitment and retention in STEM degree paths and, hence, the workforce. Thus, developing focused curricula and support structures for introductory mathematics courses is key to cement foundational content mastery and help expand undergraduate students' educational and career options (Cohen, 1995; Hemmings & Kay, 2010). By providing an environment that allows more time for faculty-student and peer-to-peer interactions, students can have positive mathematics experiences that can motivate them to continue pursuing a STEM degree (Lichtenstein et al., 2007; Watkins & Mazur, 2013). Additionally, besides the academic benefits of increased passing rates, there are financial benefits for increased student success including a decrease in students retaking the course (i.e., paying additional tuition and excess credits) as well as savings on instructional and infrastructure resources required in serving repeat students.

These results add to previous research demonstrating the effectiveness of high-tech/high-touch learning environments (e.g., Math Emporium model) on introductory level mathematics courses such as College Algebra. Overall, these results point to the importance of designing learning environments that leverage technology and human capital to better support STEM students. The Mastery Math Lab and other Math Emporium models should serve as examples for academic leaders across higher-education institutions to adapt and implement learning structures to better support STEM students. Overall, our study highlights the importance and impact that student-centered initiatives have on student personal and academic success. Our work suggests that students valued the individualized support from fellow peers, undergraduate Learning Assistants (LAs), and MML faculty, as they provided guidance and mentorship. Students benefit from this program by having increased passing rates, thus encouraging degree completion and timely graduation. Financial incentives for implementing such evidence-based student-centered approaches at other universities include saving teaching costs and faculty time.

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Appendix. Supplementary Table

Item Prompt	4-point Likert Scale options
How much did the Math Lab help you succeed in this math course?	"Not at all", "A little", "A moderate amount", and "A lot"
How well did the assigned hours for Math Lab meet your needs?	"Spent more time in the lab", "Lab time was about right", "Finished in less than lab time", and "Never needed lab time"
"Indicate how much you agree with the following statements about LAs"	
The LA seem to enjoy helping students in the class	"Agree", "Somewhat Agree", "Somewhat Disagree", and "Disagree"
The LAs help students feel confident that they can learn	
The LAs help students understand the course material	
The LAs are patient with students' questions	