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Mathematics Preparatory Workshops to Foster Student Success

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PROJECT REPORT

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Abstract

Mathematics preparatory workshops were offered to college students at a diverse urban undergraduate institution. The goal was to prepare students for their mathematics course, by offering non-credit bearing and free preparatory workshops. The lack of adequate preparation for mathematics courses is a barrier for student engagement in future STEM courses. We believe that by providing preparatory workshops, we can improve not only the success but access for students in foundational mathematics courses. The workshops allowed students to engage with the course content in a rigorous and intensive manner prior to the start of the semester. Students who participated in the workshops are more likely to be better prepared when enrolled in the credit-bearing course.

Introduction

New York City College of Technology (City Tech), a designated Hispanic-Serving Institution in an urban metropolitan area, provides education in science, technology, engineering, and mathematics (STEM) to a diverse student population. As of fall 2021, the student ethnicity/demographics at the college were 34.1% Hispanic students, 26.8% African American, 20.9% Asian, 11.4% White, 4.0% Nonresident alien, 2.2% two or more races,

0.4% American Indian or Alaskan Native and 0.2% Native Hawaiian or Pacific Islander. As a primarily undergraduate institution, the college offers associate and bachelor's degree programs. Some associate degree programs serve as a pathway towards a bachelor's degree with the advantage of enabling students to take prerequisite and developmental courses. Often referred to as "two plus two" (two-year associate and two-year bachelor's), this model enables students to start in an associate degree program while taking prerequisite and developmental courses and continue into the bachelor's program. This model provides a path for students to enter a STEM program even if there are gaps in their mathematics and science coursework in high school.

The college's mission is to prepare students for applied and technical careers by providing access to opportunities which include interdisciplinary and 'place-based learning'. Celebrating its 25th year as a Hispanic Serving Institution, the college fosters practices which promote equity for its diverse student population (City Tech, n.d). Furthermore, students are often engaged in high impact practices, such as undergraduate research, which can focus on community-based or local issues, such as water quality (Galford, 2017; Samaroo, 2022) or integration of STEM into the elementary school curriculum (Samaroo, 2018), alongside other projects that include peer led team learning (Han, 2022).

The mathematics department at our college offers more than two hundred sections of mathematics classes, with two-thirds of them considered gateway[1] classes to a student's chosen degree path. These include quantitative reasoning, college algebra and trigonometry, precalculus, calculus 1 and calculus 2, and are taken by 4,000-5,000 students every semester. In STEM disciplines, this often results in a lengthy sequence of courses where one is a prerequisite to the next. Worse yet, these courses are often ranked among the most failed courses at the institution. Gateway mathematics courses with high failure rates is likely to deter students in their STEM pursuit, leading to high attrition and low graduation (Sithole, 2017).

The preparation of students for college courses is more problematic than ever due to the well-documented learning loss experienced by students in recent years (Gordon, 2021; Moscoviz, 2022). One of the key areas of significant learning loss is in mathematics (NEA, 2022). The problem also points to increased inequity in access to quality education during the pandemic among underrepresented minorities and underserved populations (NEA, 2022). Examining the demographics found that minority students and students with financial needs tended to be those starting at developmental level or needing prerequisite content support (Attewell, 2006; Logue 2016).

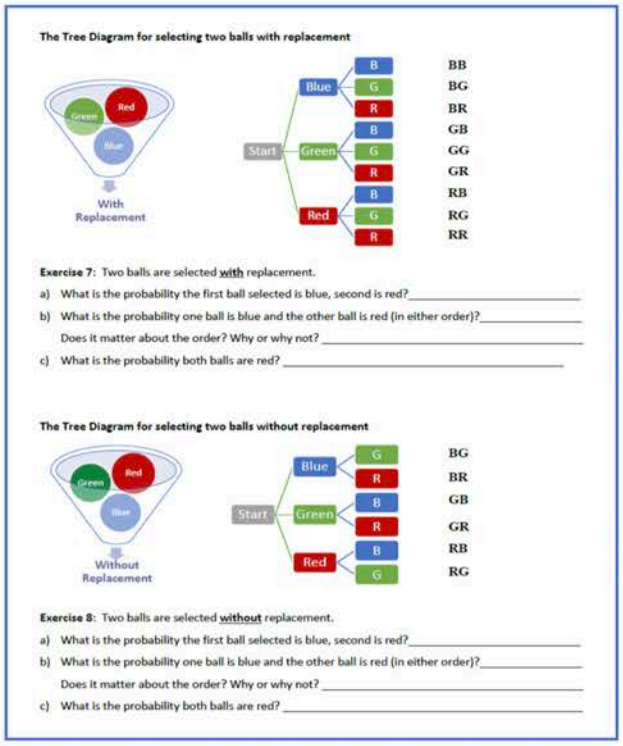
Recognizing that mathematics is the foundation of any STEM program, and that student success and timely completion of prerequisite mathematics courses strongly impact their ability to complete the STEM major (Frost, 2017), we implemented at our institution low-stakes, high-impact preparatory workshops designed to help bridge the learning gaps. In literature review, we found only few articles reporting on "preparatory workshops", "bootcamps" or "bridge programs". Most reported that there is a strong need to prepare and support students especially in the first year of college (Alavi, 2020; Campbell, 2015; Frost, 2017; Jura, 2022; Reisel, 2014). Some bridge programs range from three to four weeks. Clune et al. reported on the success of a mathematics bootcamp for graduate students (2022). Such programs, whether workshops or bootcamps, benefit students beyond the subject matter; they help provide study skills, critical thinking, college resource awareness, and they are important in the transition and the mental preparation for college (Alavi, 2020; Jura, 2022). The goal of this paper is to disseminate the work from our mathematics preparatory program for undergraduate students and to provide a model for practitioners.

Workshop Design

The key goal for our preparatory workshop is to improve student success in mathematics courses. We identified those courses that are gateway in degree programs and designed a week-long workshop to provide a review of the prerequisite materials and an introduction to the course. The typical design of the workshop is for four

1 We define gateway mathematics courses as the foundational courses students need to complete in their first year of studies for a specific degree program. These courses can also be a pre- or co-requisite to other major courses required for a degree. For example, calculus is a prerequisite to certain engineering courses at our college. Calculus can also be considered a gateway course in the Applied Mathematics major, for example, as it is the first required course in a sequence of courses for that degree.

FIGURE 1. Samples of Workshop Materials



The Tree Diagram for selecting two balls with replacement

Exercise 7: Two balls are selected **with** replacement.

a) What is the probability the first ball selected is blue, second is red?_____

b) What is the probability one ball is blue and the other ball is red (in either order)?_____

Does it matter about the order? Why or why not? _____

c) What is the probability both balls are red? _____

The Tree Diagram for selecting two balls without replacement

Exercise 8: Two balls are selected **without** replacement.

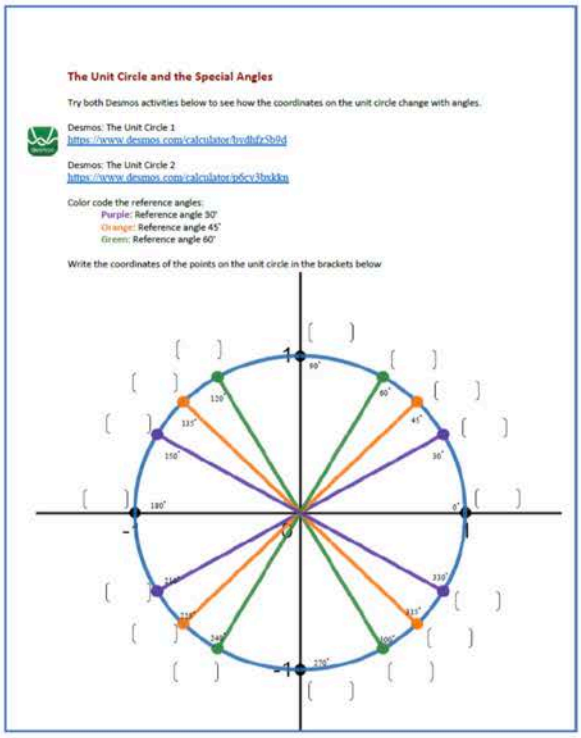
a) What is the probability the first ball selected is blue, second is red?_____

b) What is the probability one ball is blue and the other ball is red (in either order)?_____

Does it matter about the order? Why or why not? _____

c) What is the probability both balls are red? _____

Quantitative Reasoning: Demonstrating the concept of probability with or without replacement



The Unit Circle and the Special Angles

Try both Desmos activities below to see how the coordinates on the unit circle change with angles.

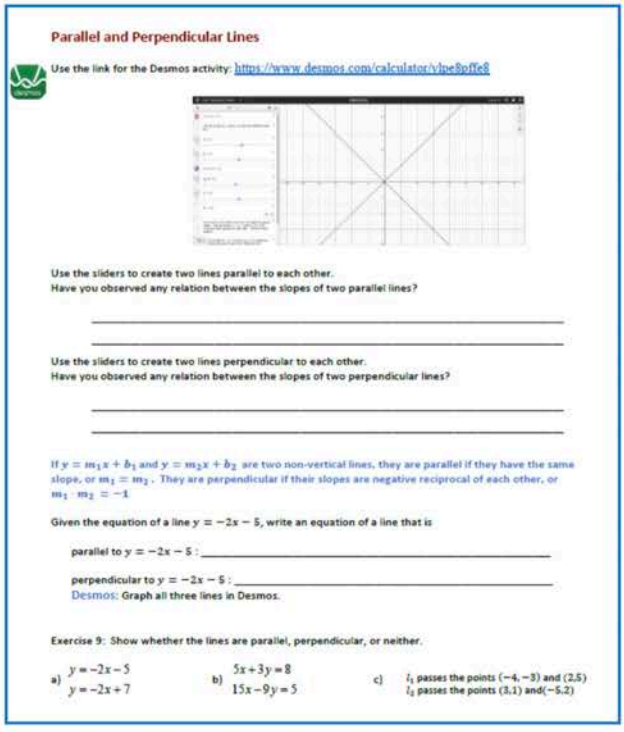
Desmos: The Unit Circle 1
https://www.desmos.com/calculator/hvdhfz5bfd

Desmos: The Unit Circle 2
https://www.desmos.com/calculator/p6cy3bxkkn

Color code the reference angles:
Purple: Reference angle 30°
Orange: Reference angle 45°
Green: Reference angle 60°

Write the coordinates of the points on the unit circle in the brackets below

Trigonometry: Introducing unit circle using Desmos and the color-coding of the special angles



Parallel and Perpendicular Lines

Use the link for the Desmos activity: https://www.desmos.com/calculator/vlpe8pffe8

Use the sliders to create two lines parallel to each other.
Have you observed any relation between the slopes of two parallel lines?

_____

_____

Use the sliders to create two lines perpendicular to each other.
Have you observed any relation between the slopes of two perpendicular lines?

_____

_____

If $y = m_1x + b_1$ and $y = m_2x + b_2$ are two non-vertical lines, they are parallel if they have the same slope, or $m_1 = m_2$. They are perpendicular if their slopes are negative reciprocal of each other, or $m_1 \cdot m_2 = -1$

Given the equation of a line $y = -2x - 5$, write an equation of a line that is

parallel to $y = -2x - 5$: _____

perpendicular to $y = -2x - 5$: _____

Desmos: Graph all three lines in Desmos.

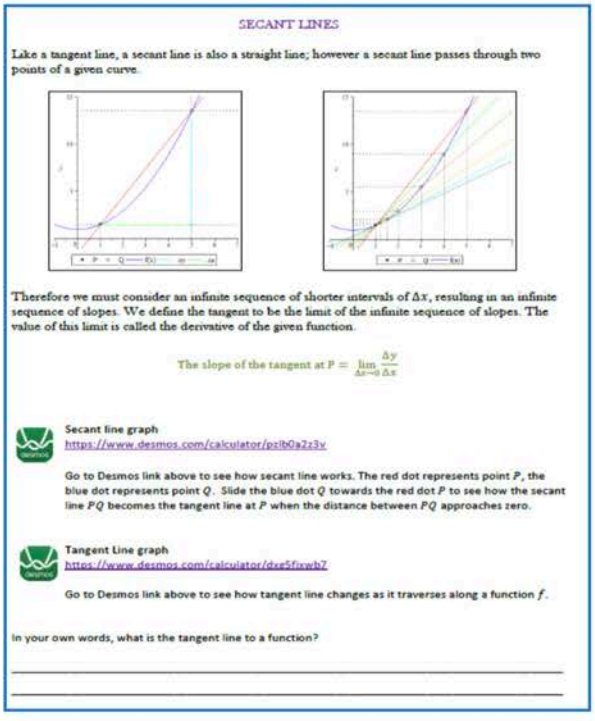
Exercise 9: Show whether the lines are parallel, perpendicular, or neither.

a) $y = -2x - 5$, $y = -2x + 7$

b) $5x + 3y = 8$, $15x - 9y = 5$

c) l_1 passes the points $(-4, -3)$ and $(2,5)$; l_2 passes the points $(3,1)$ and $(-5,2)$

College Algebra: Observing the relations of parallel and perpendicular lines using Desmos



SECANT LINES

Like a tangent line, a secant line is also a straight line; however a secant line passes through two points of a given curve.

Therefore we must consider an infinite sequence of shorter intervals of Δx, resulting in an infinite sequence of slopes. We define the tangent to be the limit of the infinite sequence of slopes. The value of this limit is called the derivative of the given function.

The slope of the tangent at $P = \lim_{\Delta x \to 0} \frac{\Delta y}{\Delta x}$

Secant line graph
https://www.desmos.com/calculator/pzlb0a2z3v

Go to Desmos link above to see how secant line works. The red dot represents point P, the blue dot represents point Q. Slide the blue dot Q towards the red dot P to see how the secant line PQ becomes the tangent line at P when the distance between PQ approaches zero.

Tangent Line graph
https://www.desmos.com/calculator/dxe5fixwb7

Go to Desmos link above to see how tangent line changes as it traverses along a function f.

In your own words, what is the tangent line to a function?

_____

_____

Calculus: Introducing the concept of tangent line by observing the changes in secant line graphs on Desmos

days at three hours a day for a total of twelve hours. For our college algebra and trigonometry with corequisite, designed for students with greater needs for remediation and reviews, we offer a slightly longer workshop for five days at three hours a day for a total of fifteen hours. The workshops are strategically scheduled right before the beginning of the semester (in summer, August and in winter, January), so students would be motivated and mentally ready on the first day of class.

The workshops are low stakes in the sense they do not bear any credits or grades, and are completely voluntary and open to all students. At our institution, the workshops are funded by First Year Programs and are offered free of cost to students. Recruitment for the workshops is through college email announcement, recommendations by the instructors or departments, or through First Year Programs and other support services. There is a required registration process for the workshop which allows us to identify the students and follow their progress in the semester.

In designing the workshops, we considered the following aspects:

- **Content support.** Each workshop is specifically designed to prepare students for a particular course. A corresponding workbook is created for each workshop to provide the content materials which include prerequisite review as well as introductory topics that students may see again in the course. The workshop instructors are recruited from among the mathematics faculty, typically those with experience teaching the course.
- **High-impact pedagogies.** High-impact active learning pedagogies are incorporated into the workshop and the workbook design, such as exploratory learning, collaborative learning, hands-on problem-solving, real-world applications, and the use of visualization for the demonstration of concepts (Abate, 2022; Presmeg, 2006).
- **Peer-support system.** The peer-led team learning (PLTL) is an important component of the support system where peer leaders recruited from among the upper-class students in various STEM majors to support and facilitate either one-on-one learning or group discussions in the workshops (Liou-Mark, 2015). Another importance of the PLTL program is the "role modeling" impact by the peer leaders whom we made strong efforts to recruit from women and underrepresented minorities.
- **Equitable and inclusive access.** The workshop design considers academic, financial, and emotional support in providing equitable and inclusive access, adopting high impact strategies to support women and underrepresented minority students. The pedagogical strategies mentioned above, as well as tuition-free workshops, the open-access resources, the PLTL support, and the use of visualization in the workbook design are all aiming to increase learning opportunities and reduce challenges.

Developed over the years, we have expanded our workshops to support six mathematics courses. Other than Quantitative Reasoning, which is considered the gateway mathematics for non-STEM majors, the other five courses are part of the STEM sequence required by engineering, mathematics, computer science, and some sciences such as computational physics and applied chemistry. Students who begin their mathematics with college algebra (based on college placement exams), often face a lengthy mathematics sequence. The college algebra course is the most enrolled course in the mathematics department. We present below a brief description of each course and its corresponding workshop:

1. **Quantitative Reasoning** is a course designed for non-STEM majors who need a review of equations, problem-solving and basic probability, and statistics. The workshop incorporates real-world data such as COVID-19 or Census data which are relevant to students and their communities.
2. **College Algebra and Trigonometry with Corequisite** is a course with additional hours of corequisite support designed for students who can benefit from additional algebra review. For many STEM majors, this is the first of their STEM mathematics sequence. The workshop starts with a review of elementary and intermediate algebra topics with emphasis on addressing common mistakes and pitfalls.
3. **College Algebra and Trigonometry,** same as (2) above, is the first of STEM mathematics sequence. The workshop puts greater emphasis on introduction to trigonometry because students tend to have difficulties with trigonometric concepts.

4. **Precalculus.** The workshop focuses on the studies of functions and their characteristics using graphs and visualization tools such as Desmos.
5. **Calculus I.** The workshop incorporates numerous graphs and visualizations to demonstrate the related concepts. The workshop provides "just in time" review of algebra.
6. **Calculus II.** The workshop focuses on both concepts and techniques, as well as provides "just in time" review of algebra and trigonometry needed in integration.

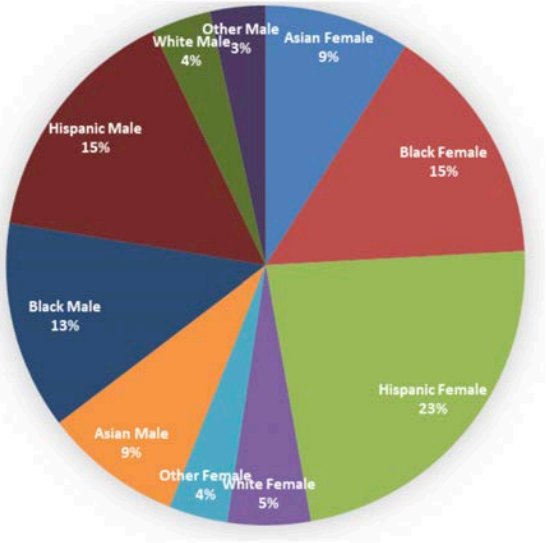
The freely accessible corresponding workbooks focus on concept understanding through visualization, hands-on problem solving, and real-world applications. The design of the curriculum offers targeted lessons that anticipate the immediate needs of the student providing relevant review materials with new content. This not only helps review a topic but also applies it right away in problem-solving. Below, we share some sample workbook materials.

Effectiveness of the Workshops

Presented in this section is a summary of findings from the workshops offered in summer 2019, summer 2020, and summer 2021. The workshops were in person in summer 2019 and online in summer 2020 and 2021. Of the total 464 participants in the workshops, 417 registered for the corresponding courses in the Fall semester immediately after the workshops, while the remaining 47 students either did not take math in the immediate semester or took a course different from the workshop in which they participated. These 47 students were included in the demographic data but excluded from the grade distribution data.

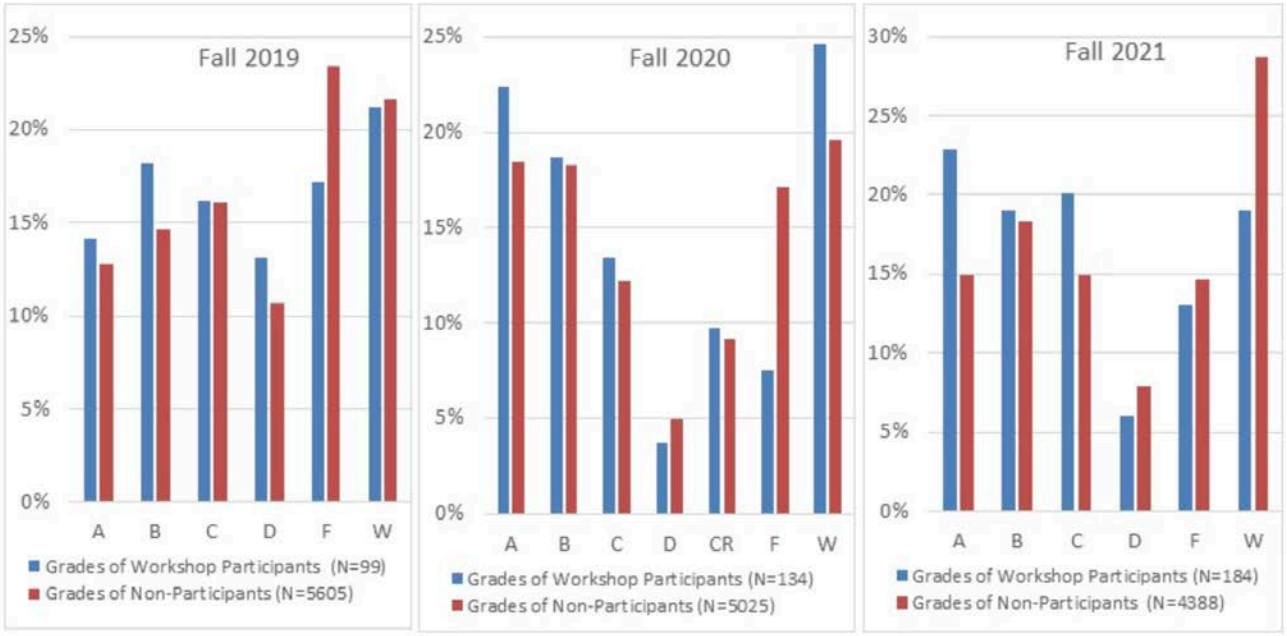
1. The demographic data of the workshop participants from summer 2019, 2020, and 2021 shows that 56% were female, and 73% were African American, Hispanic, or other (Native American, Pacific Islander, two or more races). These numbers are significant compared with the institution's enrollment data which consists of 46% women and 67.7% African American, Hispanic, and other (Figure 2). Given that registration for the workshop is voluntary and self-selected, the high participation rate among women and underrepresented minority groups, particularly Hispanic and African American women and men, suggests the preparatory workshops respond to the needs of women and underrepresented minority students for learning support.

FIGURE 2. Demographics of Workshop Participants During Summers 2019, 2020, 2021 (N=464)



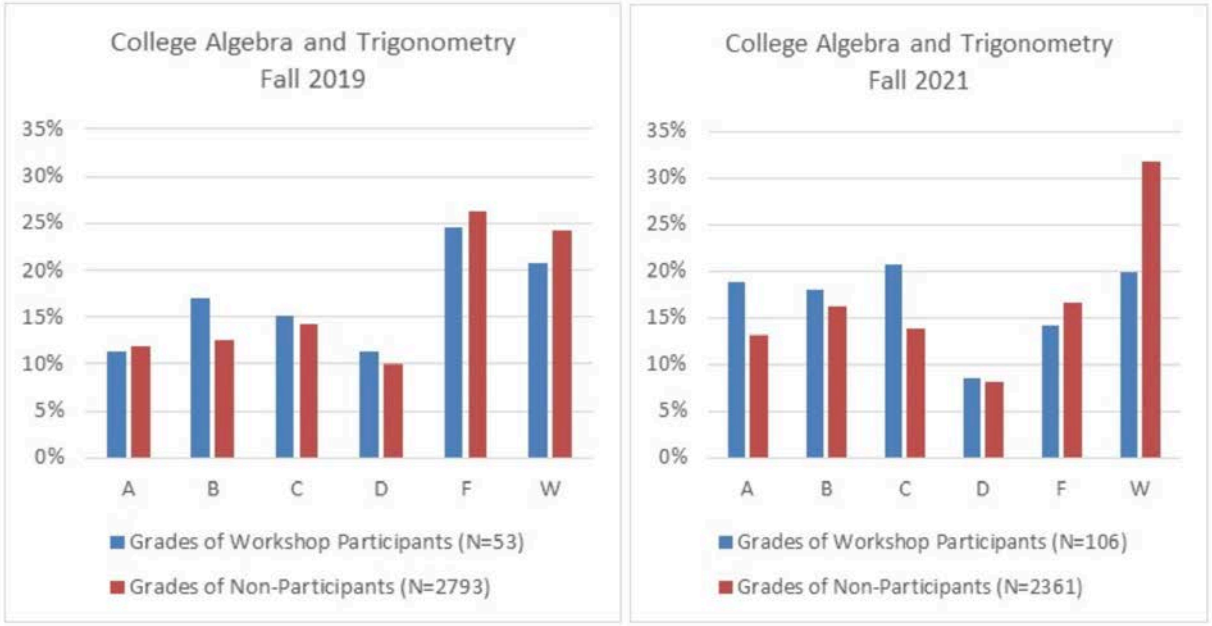
2. The grade distribution comparison indicates that students who participated in the workshop generally had a higher percentage of A, B and C grades and a lower percentage of failure (F grade) in the corresponding course as compared to students who did not participate in the workshops (see Figure 3). Overall, 56% of the workshop participants earned a grade of A, B, or C in the corresponding course in the immediate semester after the workshop.
3. While we had hoped workshop participants would show a lower withdrawal rate (W grade), a possible explanation for the higher withdrawal rate observed in Fall 2020 may be due to the special allowance for Credit (CR) and No Credit (NC) grades during the pandemic semesters. The college data grouped NC with F, rather than W grade, which may have resulted in skewed F and W grade distribution.
4. Using Chi square test to see if there is a significant difference in the grade distribution pattern of the workshop participants compared to the non-participants, we found no significant difference in the Fall 2019 and

FIGURE 3. Grade Distribution Comparison of Workshop Participants versus Non-Participants in the corresponding courses during the Fall semesters.[1]



[1] (City Tech Office of Assessment, Institutional Research & Effectiveness (AIRE), http://air.citytech.cuny.edu/data-dashboard/)

FIGURE 4. Grade Distribution Comparison of Workshop Participants versus Non-Participants in College Algebra and Trigonometry (with or without corequisite) (Fall 2019 and Fall 2021)[1]



[1] (City Tech Office of Assessment, Institutional Research & Effectiveness (AIRE), http://air.citytech.cuny.edu/)data-dashboard/data-dashboard/)

Fall 2020 data; but there is significant difference in the Fall 2021 data.

5. In desegregated comparison, students who participated in the workshops for College Algebra and Trigonometry (including both the extended course with corequisite and the regular course without the corequisite) showed a higher percentage in earning A, B, C grades and a lower percentage of earning F and W grades. See Figure 4, which also provides a pre-pandemic (Fall 2019) and post-pandemic (Fall 2021) comparison for the same course. The post-pandemic data shows an exceedingly high withdrawal rate (32%) among students who did not participate in the workshops.

6. The participation rate of the workshop among registered students in the course has increased from 1.7% in Fall 2019 to 2.6% in Fall 2020 and to 4.0% in Fall 2021. This seems to indicate that more students feel the need for course review and learning support. We think changing the workshop to the online format in 2020 and 2021 may have contributed to the increased participation. Students have also indicated that they preferred online workshops.

At the conclusion of the winter 2022 preparatory workshops, students were asked for (voluntary) feedback. Of the 55 students who responded, a significant majority agreed or strongly agreed that the workshop was helpful. Overwhelmingly, students strongly agreed that the instruction was helpful, an indication that students connected with the instructor despite this being a short one-week program.

We also asked the workshop instructors to gauge their student response or receptiveness towards the workbook; they reported positive responses and that the visual activities and graphs from the workbooks were very helpful. Regarding student engagement, instructors reported that students were actively engaged. One instructor commented, "Best online workshop that I've taught."

Conclusion

Student access to the preparatory workshops described in this paper seems to show an increase in student success in mathematics courses. Students who participate in preparatory workshops are more likely to be better prepared and show better results when taking the credit bearing course. In addition, these students are taking responsibility for their own learning since participation in the non-credit bearing workshops is completely voluntary. The preparatory workshop offered at our college focuses on bridging learning gaps in mathematics, however, this should not be exclusive to mathematics. Preparatory workshops in other first-year courses can be just as beneficial, especially those in STEM requiring foundational knowledge, such as chemistry, biology, or writing.

We share this work because it is low stakes with measurable impact and can be easily replicated for colleges who seek to address equity in student learning. We summarize additional benefits here for those who consider designing and implementing a preparatory workshop:

- A preparatory workshop may be offered in targeted discipline support based on needs.
- A preparatory workshop is easy to develop and flexible in length. The workshops may range from a few hours of review to a more extensive course prep.
- A preparatory workshop not only helps students review for a course, but it also helps prepare students with college readiness skills and mental state.
- The cost-benefit analysis shows a preparatory workshop before the semester is an efficient way to support students on a limited budget.
- Since there is no requirement for grades, the curriculum can be more creative and customized to students' skill level.

We believe that students respond favorably to the workshop because they view the instructors as helping instead of judging and are more likely to bond and enjoy the experience of learning.

In conclusion, we found that the one-week mathematics preparatory workshops just prior to the start of the semester were helpful in building motivation, increasing learning success, and providing equitable and inclusive support for students, in particular women and underrepresented minorities. Although we could not fully determine whether the post-pandemic workshops had more impact than the pre-pandemic workshops, we believe the need for learning support is stronger than ever, and the workshop is an effective way of providing a valuable foundation.

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About the Authors

Sandie Han is a Professor of Mathematics at New York City College of Technology. She has extensive experience in program design and administration, including serving as the mathematics department chair for six years, PI on the U.S. Department of Education MSEIP grant and Co-PI on the NSF S-STEM grant. Her research area is number theory and mathematics education. Her work on Self-Regulated Learning and Mathematics Self-Efficacy won the CUNY Chancellor's Award for Excellence in Undergraduate Mathematics Instructions in 2013. She is passionate about increasing student engagement and participation in STEM, particularly to empower women and underrepresented minorities. She started the CUNY Celebrates Women in Computing conference and is currently the 2022 – 23 faculty leadership fellow in CUNY Office of Undergraduate Studies, Academic Programs and Policy serving in the role of Assistant Dean for Academic Technology & Pedagogy.

Diana Samaroo is a Professor in the Chemistry Department at NYC College of Technology in Brooklyn, New York. She has experience in curricular and program development, as well as administration as the Chairperson of the Chemistry Department for six years. She has mentored undergraduates under the support of Emerging and Honors Scholars program, CUNY Service Corps, Louis-Stokes for Alliance Minority Participation (LS-AMP) and the Black Male Initiative programs. She serves as co-PI on several federal grants, which include NSF S-STEM, NSF RCN-UBE, and NSF HSI-IUSE grants. With a doctoral degree in Biochemistry, Dr. Samaroo's research interests include drug discovery, therapeutics and nanomaterials. Her pedagogical research is in peer led team learning in Chemistry and integrating research into the curriculum.

Janet Liou-Mark was a Professor Emeritus of Mathematics at NYC College of Technology. Her research interests included peer-led team learning, mentoring, interdisciplinary learning, and enhancing diversity in STEM. Dr. Liou-Mark received thirteen awards for her excellence in education, which included the 2011 CUNY Chancellor's Award for Excellence in Undergraduate Mathematics Instruction and the Mathematical Association of America Metropolitan New York Section 2014 Award for Distinguished Teaching of Mathematics. Dr. Liou-Mark was co-principal investigator on several National Science Foundation grants, as well as Department of Education Minority Science and Engineering Improvement Program grant.

Lauri Aguirre is the Director of First Year Programs (FYP) at New York City College of Technology. In this role, she has administered and designed programs for new students, focusing on their acclimatization of basic academic skills, college preparedness and student success. Programming has included the First Year Summer Program immersion courses and workshops in English and mathematics, First Year Learning Communities, City Tech 101: A Student Success Workshop, the FYP Peer Mentoring program, and the student handbook, *The Companion for the First Year at City Tech.*

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