
AC 2011-2551: IMPROVING MATH SKILLS THROUGH INTENSIVE MENTORING AND TUTORING

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Improving Math Skills through Intensive Mentoring and Tutoring

Abstract

Mathematic skills are essential for the career success of students in Science, Technology, Engineering and Mathematics (STEM) programs. As prerequisite for major course requirements, passing rate in math courses is an important factor for the retention and graduations rates for STEM majors. This paper presents a successful practice to improve students' math skills through intensive mentoring and tutoring. A group of students participate as a cohort in a summer bridge program supported by an NSF grant. They take an introductory math class under the same schedule and requirements as other regular classes. In addition, they get extra exercises with the help of faculty mentors and peer tutors. Comparison statistics between the students in the summer bridge program and other regular classes show a significant improvement in math skills for the summer program. The study demonstrates that guidance and practice are keys to improve math skills.

1. Introduction

Since mathematics courses are general education requirements for college degrees, improving mathematics skills is essential for college students to complete their degrees. Science, Technology, Engineering and Mathematics (STEM) programs generally require more mathematics credits as prerequisites for major courses and as a fundamental tool for future careers. Mathematics skills are even more important for STEM students' successes¹⁻⁵.

Essex County College is a large two-year urban community college of more than 13,000 students with 79% minority population, including 52% African American students and 23% Hispanic students. All entering students are required to take a standardized placement test (Accuplacer) which consists of English and mathematics. They are placed into different levels of English and mathematics classes, including remedial/developmental classes, based on their scores on the placement test. There are two developmental mathematics courses, *MTH086 Introductory Algebra* (4.5 credits) followed by *MTH092 Elementary Algebra* (4.5 credits). Most associate degrees in STEM programs require a number of additional college mathematics credits after the developmental mathematics courses. The sequence of mathematics courses leading to Associate in Applied Science (A.A.S.) degrees generally include *MTH086*, *MTH092*, *MTH100 Introductory College Mathematics* (4 credits), *MTH113 College Algebra with Trigonometry* (4 credits), and *MTH114 Unified Calculus I* (4 credits). The Associate in Science (A.S.) degrees usually require a different sequence of mathematics courses, *MTH086*, *MTH092*, *MTH100*, *MTH119/120 Pre-calculus I/II* (4/4 credits), *MTH121/122 Calculus with Analytic Geometry I/II* (4/4 credits), and additional advanced mathematics courses. In general, the mathematics requirements in the catalog start from *MTH113* and up for the A.A.S. degrees, whereas for A.S. degrees, *MTH121* and up courses will count toward mathematics requirement; all lower mathematics courses are prerequisites. Many students start their first semester by taking a

developmental mathematics course, and some of them may stay in developmental level math courses for an extended period of time, thus unable to take STEM courses. These students could drop out of college or change to non-STEM majors with fewer required courses in mathematics. The retention and graduation rates of STEM majors are largely dependent upon their success in passing developmental and lower level mathematics courses.

In fall 2006, the National Science Foundation (NSF) awarded the college a grant in Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP). The goal of the grant was to improve enrollment, retention, and graduation rates in STEM degree programs. With the support of the grant, we started a Summer Bridge Program (SBP), among other strategies, with an emphasis on helping students to improve mathematics skills and pass the developmental mathematics courses. The Summer Bridge Program seems to be very successful because the great majority of participating students have passed the developmental math course and moved up to college level math and major courses in the subsequent fall semester.

2. The Summer Bridge Program

The first NSF supported Summer Bridge Program (SBP) at Essex County College took place in the Center for Technology in the Summer I term of 2008, which lasted from April 30 to June 18. Participants in the SBP included 35 students, 5 faculty, and 2 tutors (Figure 2). Every student took two developmental courses: one math course (either *MTH092 Elementary Algebra* or *MTH100 Introductory College Mathematics* depending on his/her placement or prerequisite) and one technology course (either *CSC100 Fundamentals of Computer Science* or *ENR100 Introduction to Engineering Technologies and Science* depending on his/her discipline). Engineering related majors were placed into *ENR100*, and other STEM majors were assigned to *CSC100*. In both *CSC100* and *ENR100* classes, students learned about career opportunities, had hands-on laboratory projects, and developed necessary and essential skills for their major courses. The faculty mentors and instructors included 4 full-time faculty, including the PI, and one adjunct faculty who also worked as the part-time MESA Center Coordinator for the grant program. All faculty were in STEM disciplines. Two math faculty taught the *MTH092* and *MTH100* classes respectively; one engineering faculty taught the *ENR100* class; and the adjunct instructor in computer science discipline taught the *CSC100* class. Both tutors were sophomore engineering students who were near completion of their A.S. degrees with outstanding GPAs.

Like other regular classes in the summer terms, Summer Bridge Program classes last less than two months versus nearly four months for classes run in spring and fall semesters. A 3-credit class meets four days a week in a summer term rather than twice a week in a spring or fall semester. Each class period lasts an hour and twenty minutes whether conducted in a summer term or a regular semester. In addition to class lectures, all participants in the SBP, including students, tutors, and faculty, are required to attend a 3-contact-hour recitation session every day in which faculty and tutors are on site to help students while they are completing assignments and projects as well as doing additional practices.

Since *MT100* is a bridge course between the developmental mathematics courses (*MTH086* and *MTH092*) and higher level mathematics courses (*MTH113/114* or *MTH119/120/121/122*) which

are fundamentals to STEM courses, it is critical for any STEM students to pass *MTH100* in order to advance to required courses in higher level mathematics and take STEM majors courses. Therefore, the current study focuses on the students enrolled in the *MTH100* rather than those enrolled in the *MTH092* offered by the Summer Bridge Program. It compares the performance of the SBP students in *MTH100* with that of the students enrolled in regular *MTH100* classes offered in the same summer term to see whether the SBP was successful in helping the students succeed in developmental math and making them ready to take the required college level math courses in the subsequent fall semester.

To recruit students for the Summer Bridge Program, we posted flyers and visited classes in the spring 2008 semester. All applicants who met the basic qualifications (STEM majors, passing the prerequisite course with a “C” or above grade, and other NSF grant requirements) were accepted. Twenty three students were enrolled in the SBP *MTH100* class. With the support of the grant and additional financial support from the college, the Summer Bridge Program provided tuition, textbook, and lunch to its participating students.



Figure 2. Students and Staff in the 2008 Summer Bridge Program

3. Strategies to Improve Math Skills

3.1 Intensive Recitation Session

With the belief that an important technique in building math skills, or probably any skills, is through practice, we require that students enrolled in ECC's SBP attend a 3-contact-hour recitation session every day, in addition to the class lectures. The recitation session, devoted mainly to practice and exercises in mathematics, provides students with an opportunity to immediately practice intensively things that they have just learned from class. All participants, including students, tutors, and faculty, must attend the 3-contact-hour recitation session every day. Faculty and tutors attend the recitation session to guide and assist students while they are working on their assignments and projects. It is true that regular developmental math classes already provide a tutorial session in addition to the lectures. However, it is only a one-hour open lab. Students go to the lab at their convenient time to get help from tutors. The tutorial lab shows on the course schedule with one credit hour, but it is not recorded on the transcript for any credit. As a result, some students opt not to go to the lab. Compared to regular developmental math classes, the SBP math classes provide students with these advantages: a) attending the recitation session regularly as a cohort; b) getting immediate feedback on their work and proper guidance from the instructor who can readjust his/her teaching plans according to students' mastery and progress; c) getting tutoring assistance from experienced tutors in STEM majors, d) engaging in intensive and systematic practices with supplements, including computer software, chosen by the instructor; and e) enhancing the understanding of the new material through immediate hands-on applications of STEM projects.

3.2 Faculty Mentoring

Faculty mentoring plays a crucial role in promoting STEM majors and cultivating interest in pursuing STEM careers. Many students who originally show an interest in STEM majors often take only developmental English and math classes when they start their college studies because they have not met the basic skills requirements in mathematics and English. Some of these students ultimately lose their interests in STEM majors as they remain in developmental classes for an extended period of time without ever taking college level major courses and getting to know the STEM faculty. The academic advisement and planning assistance provided by STEM faculty to the students through the SBP help develop academic relationships between faculty and students, cultivate and retain students' interest in STEM majors, and motivate students to work hard on the developmental courses in order to advance to college level math and major courses in STEM programs.

ECC's SBP also provides junior faculty good opportunities for professional development. In participating in the SBP, they are encouraged to experiment and innovate new pedagogies and technologies for teaching and curriculum implementation with a cohort group of students who are often more focused and motivated. Teaching in the SBP also allows the faculty to demonstrate their services to the college beyond conventional academic programs.

3.3 Peer Tutoring

Tutors play a significant role in helping SBP students to succeed. Selected tutors are outstanding STEM students who are minority students themselves and serve as role models for the newly enrolled college students in the SBP. They provide advice to the SBP students from their unique perspectives, and support and connect with them in ways that faculty cannot. Both tutors in the 2008 SBP program have graduated and transferred to four-year universities since the summer. They continue to serve as inspirations for the SBP students as the latter still look up to them for future career paths and advancement.

3.4 Supporting Services and Activities

In addition to the close daily contact with the instructors and tutors, students in the SBP also receive individual advisement from other program staff and participate in many academic activities. All students are required to develop a personalized academic plan and semester-by-semester class schedules for degree attainment. The SBP has organized seminars and workshops at which external experts presented STEM career opportunities and alumni shared their learning experiences before and after transferring to four-year universities. Field trips, such as visits to industries and four-year universities, are also arranged to help students develop a holistic view of the academic programs and a better understanding of the career possibilities. These supporting services and activities provide the students a window into the advanced academic programs and future career prospects and create a unique environment for the students to retain their interest in STEM programs and enthusiasm in pursuing STEM careers.

3.5 Cohort

Students in the SBP are all STEM majors working as a cohort. There are a lot of benefits to the learning community created by the cohort. Because students attend the same class and recitation, participate in the same academic activities, and even eat lunch together in the cafeteria, they get to know each other better and a strong social bond with one another is developed as a result. As they often work closely with each other on various group projects and designs, they naturally form deeper academic relationships. All these make it easier for them to seek help and support from each other in dealing with difficulties they encounter in their personal and academic lives. In addition, faculty and tutors' presence in the daily recitation session allows the students to approach them and seek academic advice from the "authoritative" figures.

4. Subjects of the Study

The study compares the academic performance of two groups of students: SBP group and control group. The SBP group includes students who were enrolled in the SBP *MTH100* class offered in summer 2008, while the control group includes students who were enrolled in three regular *MTH100* classes run in the same summer term of 2008. Only 3 of the 8 regular *MTH100* classes were selected for the study because the students were under similar conditions as the SBP students. Like the SBP *MTH100* class, the three regular *MTH100* classes were day classes in

which the enrolled were generally full-time students, they were taught by full-time faculty, and they used the same textbook and departmental examination as the passing and exit criteria.

5. MTH100 Course Outcomes of the Two Groups

5.1 Comparison of the Mean Scores of the SBP and Regular Classes

The average or mean grade scores of the two groups in *MTH100* are listed in Table 5.1. The mean grade scores of these students in the pre-requisite course *MTH092* are also listed in the table to compare the progress and improvement of the two groups of students since the lower pre-requisite course. *MTH100* requires a grade of “C” or above in its pre-requisite *MTH092*. There may be a small number of students who enrolled in *MTH100* without a regular grade in *MTH092* because they may have either passed the math component of the Accuplacer placement test, or received a waiver. The grading system is un-weighted with A = 4.0, B+ = 3.5, B = 3.0, C+ = 2.5, C = 2.0, D = 1.0, and F = 0.0.

Table 5.1 Comparison of SBP and Regular *MTH100* classes

	Students	Withdrew	Passing (≥ C)	Mean Score/Students (MTH100)	Mean Score/Students (MTH092)
MTH100-S01	23	0 (0%)	22 (96%)	3.24/23	3.06/18
MTH100-101	28	7 (25%)	16 (57%)	2.52/21	3.00/20
MTH100-103	28	7 (25%)	13 (46%)	1.86/21	2.79/26
MTH100-104	32	9 (28%)	17 (53%)	2.00/23	2.79/19
MTH100-101/103/104	88	23 (26%)	46 (52%)	2.12/65	2.85/65

SBP group = MTH100-S01

Control group = MTH100-101, MTH100-103, MTH100-104

Table 5.1 shows that the SBP students performed better in *MTH100* (*S01*) than control group students in the other three regular *MTH100* classes (*101*, *103*, and *104*). All SBP students completed the class. In contrast, 26% of the control group students withdrew from the classes. In addition, all SBP students, except one, passed the class with a grade of C and above; the course pass rate for the SBP group was 96%. On the other hand, the pass rate for the control group was only 52% for all registered students. A χ^2 -test found the difference in the course pass rates of the two groups to be statistically significant ($\chi^2 = 5.604$, $df = 1$, $p < .05$).

Not only did the SBP group have a significantly higher course pass rate than the control group, but the SBP students also did significantly better than the students of the control group in *MTH100*. A *t*-test found the mean grade score of the SBP students to be significantly higher than that of their non-SBP counterparts (3.24 vs. 2.12, $t = 3.543$, $df = 86$, $p < .001$).

The comparisons of the outcomes are also shown in Figure 5.1.

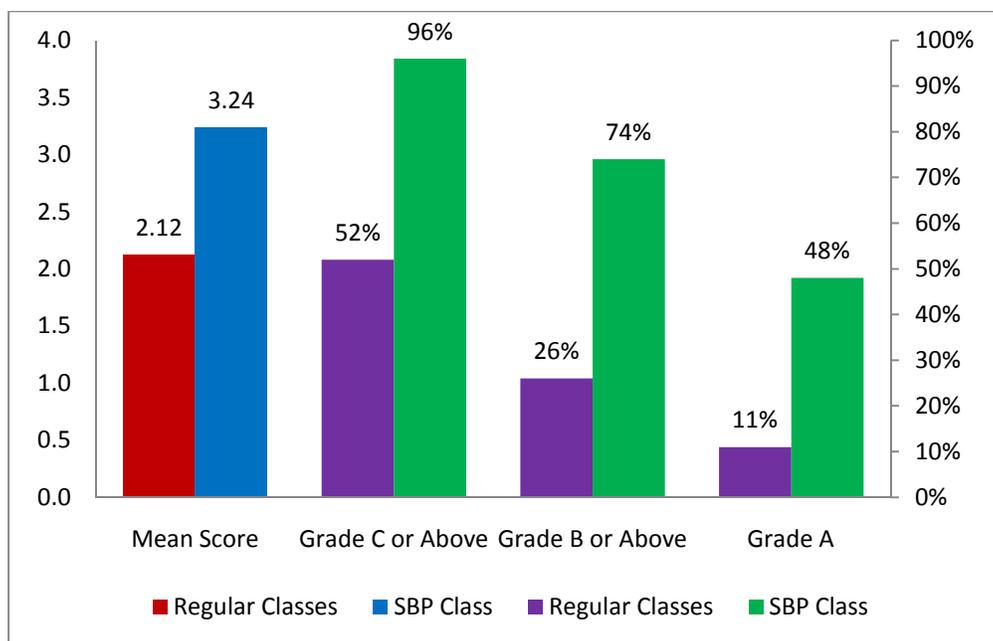


Figure 5.1 SBP vs. Regular MTH100 Classes

It is true that Table 5.1 shows that the SBP students had a slightly better mean grade score than the control group students in the pre-requisite course *MTH092* (3.06 versus 2.85). However, a *t*-test of the mean grade scores did not reveal a statistically significant difference ($t = 0.981$, $df = 81$, $p > .10$). This result indicates that the two groups started *MTH100* at more or less the same level as determined by their similar mean grade scores in the pre-requisite course *MTH092*.

Looking more closely, one can notice that the SBP students on average improved their grades in the higher level math course, from a mean grade score of 3.06 in *MTH092* to 3.24 in *MTH100*. The SBP group's 6% improvement in the mean grade score contrasts markedly with the control group's 26% decrease in the mean grade score from *MTH092* to *MTH100*.

5.2 Comparison of STEM students

It is generally believed that STEM majors are better prepared in math in high schools than non-STEM majors. Assuming that the belief is true, it is not unreasonable to claim that the SBP students performed better in *MTH100* than non-SBP students simply because all the SBP students were STEM majors. Therefore, it is necessary to compare the performance of the STEM majors in the two groups. If the SBP students also did better in the summer math course than the STEM majors in the control group, then we can eliminate STEM majors as a possible contributing factor for the SBP students' success.

All the 23 SBP students and 25 students in the control group were identified as STEM majors. The results of the performance by the STEM students from the two groups are listed in Table 5.2.

Table 5.2 Comparison of STEM Majors in the MTH100 Classes

	Students	Withdrew	Passing (≥ C)	Mean Score/Students (MTH100)	Mean Score/Students (MTH092)
MTH100-S01	23	0 (0%)	22 (96%)	3.24/23	3.06/18
MTH100-101/103/104 STEM Majors	25	2 (8%)	17 (68%)	2.07/23	2.93/23

SBP group = MTH100-S01

Control group = MTH100-101, MTH100-103, MTH100-104

As is shown in Table 5.2, the SBP students performed better in all categories than the STEM majors enrolled in the regular *MTH100* classes. Although the SBP students had a slightly better mean grade score than the STEM majors of the control group in the prerequisite course *MTH092* (3.06 versus 2.93 respectively), a *t*-test of the mean grade scores did not show a statistically significant difference ($t = 0.510$, $df = 39$, $p > .10$). However, the SBP students on average did significantly better in *MTH100* than the students in the control group (3.24 vs. 2.07, $t = 3.421$, $df = 44$, $p < .001$). Specially, their mean grade score increased 6% from 3.06 to 3.24. In contrast, the STEM students in the control group decreased 29% in the mean grade score from 2.93 in *MTH092* to 2.07 in *MTH100*. In terms of the course (*MTH100*) pass rate, the SBP group also did much better than the control group (96% vs. 68%). The SBP's course drop-out rate was 0%, whereas the control group had a course drop-out rate of 8%.

6. Academic Performance beyond MTH100

It is very encouraging to see the SBP students outperformed their non-SBP counterparts in the critical developmental math course *MTH100*. As program directors and educators, we would like to see continued success of the SBP students beyond *MTH100*. We hope that the comprehensive strategies developed by the Summer Bridge Program have helped lay a strong academic foundation for the students who can then follow their academic plan and apply study techniques to their future studies in order to pass the subsequent math courses and complete their STEM degrees on time. To examine whether the SBP had any long term effects on students' academic career, the study tracks the two groups of students to the subsequent math courses. How many of the STEM students from each group continued the required math sequence? How did they do in the subsequent math courses?

At ECC, most STEM majors are required to take additional math courses beyond *MTH100*. In general, the programs leading to Associate in Science (A.S.) degree programs require more mathematics courses than the Associate in Applied Science (A.A.S.) degree programs. In addition, A.A.S. students take more technology courses in freshman and sophomore years, but A.S. students will take most major courses in junior and senior years at four-year universities. The required math course sequence is *MTH119/120/121/122* for A.S. degrees, possibly plus additional mathematics courses, whereas the A.A.S. degrees require only *MTH113/114*. Since STEM students may take two different sets of mathematics courses, the study tracks them separately. Because some special STEM programs do not require higher level mathematics courses, the study tracks only the STEM students who were required to take additional higher level mathematics courses after *MTH100*.

6.1 Progress of the STEM Students in A.S. Degree Programs

Listed in Table 6.1 is the academic performance of the SBP students and the STEM students in the control group seeking A.S. degrees. The percentage in parentheses indicates course pass rate.

Table 6.1 Comparison of STEM Majors in Subsequent MTH119/120/121/122 Classes

	Students	Mean Score (\geq C)/Students (MTH119)	Mean Score (\geq C)/Students (MTH120)	Mean Score (\geq C)/Students (MTH121)	Mean Score (\geq C)/Students (MTH122)
2008-2009 Academic Year:					
MTH100-S01	9	3.14/7 (78%)	3.20/5 (56%)	3.00/3 (33%)	- /0 (0%)
MTH100-101/103/104	12	2.40/5 (42%)	2.75/2 (17%)	3.25/2 (17%)	- /0 (0%)
2008-2010 Academic Years:					
MTH100-S01	9	3.13/8 (89%)	2.94/8 (89%)	3.20/5 (56%)	3.33/3 (33%)
MTH100-101/103/104	12	2.29/7 (58%)	2.88/4 (33%)	3.25/2 (17%)	3.00/1 (8%)

SBP group = MTH100-S01

Control group = MTH100-101, MTH100-103, MTH100-104

As the table indicates, after the summer 2008 *MTH100* class, students from the SBP group progressed faster in the required math course sequence for A.S. degrees in the first academic year (2008-09). More students from the SBP group passed the next math course and moved on to the next higher level math courses. Their faster pace in advancing in the sequence continued to hold in the second academic year. By the spring 2010 semester, 33% of the SBP students had passed the *MTH122* course required of A.S. degree students. In contrast, only one (8%) STEM student from the control group had completed the course.

6.2 Progress of the STEM students in A.A.S. Degree Programs

The academic progress of the two groups of students in A.A.S. degrees is listed in Table 6.2.

Table 6.2 Comparison of STEM Majors in Subsequent MTH113/114 Classes

	Students	Mean Score (\geq C) /Students (MTH113)	Mean Score (\geq C)/Students (MTH114)
2008-2009 Academic Year:			
MTH100-S01	12	2.67/9 (75%)	2.83/3 (25%)
MTH100-101/103/104	5	4.00/1 (20%)	- /0 (0%)
2008-2010 Academic Years:			
MTH100-S01	12	2.67/9 (75%)	3.00/5 (42%)
MTH100-101/103/104	5	3.00/2 (40%)	3.00/1 (20%)

SBP group = MTH100-S01

Control group = MTH100-101, MTH100-103, MTH100-104

By the spring 2010 semester, 42% of the SBP students had met the math course requirement for their A.A.S. degree, whereas only one (20%) STEM student from the control group had done so. While 75% of the SBP students completed the first of the two math courses required for their A.A.S. degrees, only 40% of the STEM students from the control group did.

7. Conclusion

In this study, students who were enrolled in the summer 2008 *MTH100* class offered by the Summer Bridge Program demonstrated consistently better performance than students enrolled in other regular *MTH100* classes. Not only did the SBP students do better in the summer math course, but they also outperformed their counterparts in other required, higher level math courses as determined by their faster progress in the required math sequence and the larger number of students having met the math course requirement for their degrees. The results suggest that the intervention of the summer math course offered by the Summer Bridge Program not only achieved its short term goal of helping students pass the summer course, but also had long term effects that contributed to students' future success in higher level math courses.

Although it is difficult to pinpoint a particular contributing factor for the SBP students' success, it is perhaps reasonable to suggest that the confluence of all the various features of the SBP played the contributing role. For example, the daily intensive practice and additional exercises may have helped students sharpen their problem solving skills in math. The course instructor and tutors may have helped students tackle their particular difficulties or reinforce a new concept in a timely manner during the recitation session. The cohort approach allowed students, faculty, and tutors to develop a close academic relationship in a friendly environment that was conducive to learning. In short, faculty mentoring, peer tutoring, staff advisement and support, hands-on projects, academic planning, and other academic activities all provided effective study assistance to help students succeed in the critical summer mathematics course.

Because of the success of the 2008 SBP program and with the support of the five-year NSF grant, we have continued to offer and improve the SBP program to help more STEM students to succeed in mathematics courses, which will enable them to ultimately achieve their educational goals on time. The model of the SBP program has also been adopted by other grants and support programs at Essex County College to help improve students' mathematics skills. More longitudinal studies will follow as data become available.

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