

AC 2010-1162: PRE-COLLEGE MATHEMATICS PREPARATION: DOES IT WORK?

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Abstract

In 2008 and 2009 VCU offered a rigorous four week residential summer transition program for incoming under-represented minority freshmen in science, engineering, and mathematics disciplines. The core component of the academic program was mathematics preparation, achieved by offering a pre-calculus course. In addition, courses in science (chemistry) and study skills were offered. This paper will address the importance of offering mathematics preparation as a part of pre-college programs whose goals are to develop under-represented minority students' performance and reduce the gap between them and their peers from different races/ethnicities. In addition, it will spot light the best practices which have been identified.

Introduction

Calculus is a core subject for most of science and engineering fields and it affects student's retention in science, technology, engineering, and mathematics (STEM) disciplines during the freshmen year¹. Unfortunately, many students in STEM disciplines still consider calculus a complicated and challenging subject². Literature emphasizes that good high school mathematical knowledge leads to a good performance in the first mathematics college course, which is directly correlated with increased retention rates in STEM majors³⁻⁷. It was reported that "there is a consensus that math is the largest stumbling block causing dropout in the freshman year", regarding engineering freshmen programs⁸. Moreover, approximately two thirds of students in calculus pass the course in their freshmen year which considered a low rate for college students⁹. With regard to under-represented minority students in STEM disciplines, calculus is a major obstacle during their career decision as well⁹.

Summer transition programs play a key role in achieving necessary mathematics preparation for the upcoming academic year. As in [10] engineering "math-based" retention programs had a significant impact on students' performance on their first mathematics course. Another study revealed that there was no significant impact of such program on participant's performance¹¹. Nevertheless, the results from the same study showed that program participants' performance was at least the same as non-participants' performance. Virginia Commonwealth University (VCU), similar to many other institutions, has calculus as the first required mathematics course in the engineering curriculum. Literature connects good student performance in calculus with a good pre-calculus preparation¹². Consequently, VCU developed a rigorous four week summer transition program (STP) for incoming minority (African American, Hispanic American, and Native American) freshmen STEM disciplines in 2008. The core academic component of the program was a pre-calculus preparation course along with science and study skills courses. A four credit pre-calculus course was offered during the program's first year to prepare the students for their first mathematics course in the upcoming fall semester. All students took an on-line mathematics placement test to confirm their placement in pre-calculus. The goal of the summer course was to enhance participants' mathematics knowledge and ensure that students could start their freshman year in calculus.

The STP participants showed an outstanding performance in pre-calculus course during the program³. In reviewing feedback from the program participants and instructors, it was noticed that offering a four credit hour mathematics course is intense and challenging in four weeks. The program coordinators hypothesized student mathematics performance would still improve if the course was less concentrated and focused on traditional points of student weaknesses. As a result, a non-credit pre-calculus preparation course was offered during the second STP (in 2009). The course focused on preparing participants for their first college mathematics course regardless to their mathematical backgrounds. Pre/post math placement tests were administered to measure participants' qualifications and focus on their needs as individuals.

2009 Program description and data collection

The STP of 2009 had twenty two participants of whom twenty African Americans and two Hispanic Americans from the following disciplines: Engineering, Chemistry, Biology, and Forensic Science. The female participation was more than half of the total participation (13 out of 22 students). In both years, the program was a voluntary program; participants received an invitation letter via both mail and e-mail. Students who were interested in participating in the program sent in their applications. Then, participants selected based upon their major, high school, high school grade point average (GPA), and SAT/ACT scores. A total of 192 invitations were sent out to minority students who had been admitted to STEM disciplines at VCU for the year of 2009. This is a significant increase over the 2008 number of students (79) who selected a STEM major. However a comparable number of students applied for the STP, 34 in 2009 compared to 33 in 2008. Participants received a stipend of four hundred fifty dollars (\$450) in addition to room and board for the summer.

The STP participants' performance, for both 2008 and 2009, are compared in order to understand what works better to prepare students for their first mathematics course for the upcoming year. Students' grades in algebra, pre-calculus, calculus, and calculus II are compared separately. The software used in this study to conduct the statistical analysis is JMP 8.0.

Two surveys were administered to students during the STP, one mid-program and the second at the end of the program, after the first and final tests, respectively. The main focus of these surveys was to measure the program's perceived impact on participants' academic development in mathematics and whether or not the students are satisfied with their performance and study style. In order to get better measurement responses, participants were asked to write a reflective essay on why they did/didn't perform well on their mathematics test. Their responses were compared to their test grades and the math instructor feedback.

The STP Pre-calculus course 2009 modifications

In the 2008 STP, as described in [3], the participants enrolled in a four credit pre-calculus course. The 2008 participants showed a very good performance during the summer program. Twenty of the 22 students took the course for credit the other two audited the class. All of the enrolled students passed the course. Moreover, 15 out of 20 students passed with either an A or a B³. Thus, participants not only gained more college credits, but also they started the fall semester

with confident with their mathematical abilities and a chance to start with their peers in the first required mathematics course, calculus.

In reviewing participants' surveys, faculty feedback, and program staff observations; the program coordinators assumed that squeezing a four credit hours course into four weeks was a challenge for most students especially who had a weak background in mathematics. As a result, the four credit pre-calculus course was replaced with a mathematics preparation course with focusing on pre-calculus and the points of weakness on participants' mathematical background.

Surveys analysis

In reviewing the 2009 students' surveys, half of the students classified the mathematics preparation course as a challenging course, although the course addressed the differences in participants' backgrounds and level of knowledge in mathematics. Almost all students agreed on the program effectiveness and impact on their preparation and knowledge. Participants were asked to list the most effective ways for mathematics test preparation. The majority reported that practice problems, taking good notes, and studying frequently are the most effective ways to get good grades. Few of them listed asking for help; going to tutoring; and forming study groups as successful ways of test preparation.

The survey also studied the effectiveness of studying in groups in science and mathematics courses during college. The survey asked about student preferences with regards to studying in groups or individually; the size of the group; and the reasons why they think it is an effective way or not. Ten students responded that they prefer to study in groups, especially small ones of four or five; six answered no mostly because of their worries in getting off the task and other team members who are not motivated to work; three agreed on both ways; and one connected the study style with the subject matter.

Reflective essay responses analysis

On the last day of the program in 2009, after receiving their mathematics course grades, students were asked to write a reflective essay on: why they think they did or did not perform well on their mathematics test? Almost all students were pleased with the mathematics instructor's performance. Two students reported that the teacher was qualified and able to convey most of the class but the flow of information was going too fast. Test anxiety; lack of focus and practice of problems, and family issues were on the list of reasons that affected their performance as well.

As discussed before, the pre-mathematics preparation is an important issue in enhancing student's performance which in turn leads to a better retention rates in STEM disciplines. Thus, it was important to address the level of preparation for students before they enroll into this program and how it affected their achievement. Some students reported that the last mathematics course they took was algebra in high school. In addition, they claimed that they were unfamiliar with the course format and the college environment. A student wrote about her 9th grade mathematics class difficulty and how it negatively affected her perception of math in the following years. The following are examples of students' responses on why they performed well on their mathematics test:

“I think I did well because of the prior knowledge in this field. I also took notes and did all work that was required for me to learn the material. I also asked questions on anything I didn’t understand.”

“I did well because of my attitude toward math and I didn’t do better because I didn’t study the night before”.

“I did well because the covered material was a review”.

“I did well because I practiced the night before and already prepared in high school”.

Participants’ mathematical performance: a comparison between 2008 & 2009

Algebra

In this study, which used six 2009 STP participants in the algebra class, none of the students had an A but three passed with a B or C was observed. However, the 2008 STP participants only 2 took the algebra class during fall 2008. None of them earned an A as well, see table 1.

Table 1
Outcomes in the two groups for Algebra

Group	Outcome					Avg. Performance	total
	A	B	C	D	F		
2008	None	None	2(100%)	None	None	2.0	2
2009	None	2(33.3%)	1(16.7%)	3(50%)	None	1.8	6
total							8

Precalculus

As for the precalculus course, only 4 STP participants enrolled in the class in fall 2009, only four out of twenty two students took the class during fall 2009. None of them earned an A. However, a proportion of 0.45(9 students) of 2008 STP participants who had an A in the class was observed, see table 2.

Table 2
Outcomes in the two groups for Precalculus

Group	Outcome					Avg. Performance	total
	A	B	C	D	F		
2008	9(45%)	6(30%)	5(25%)	None	None	3.2	20
2009	None	2(50%)	1(25%)	None	1(25%)	2.0	4
total							24

Calculus

For the 2009 STP participants, six out of twenty two students registered for the calculus class in fall 2009 and one registered for calculus class in spring 2010. The 2008 STP group had 15 students who registered for the class and seven of them had either an A or a B (see table 3). As in [3], fifteen of the 2008 STP participants had the chance to start with Calculus after the STP in addition to six college credits compared to the 2009 STP participants group.

Table 3
Outcomes in the two groups for Calculus

Group	Outcome					Avg. Performance	total
	A	B	C	D	F		
2008	4(26.7%)	3(20%)	3(20%)	4(26.7%)	1(6.7%)	2.1	15
2009	2(28.57%)	3(42.86%)	None	None	1(14.29%)	2.8	6
total							21

Calculus II

Of the remaining STP students in both years, four students took higher math level, Calculus II, on fall 2008 & 2009, respectively (see table 4). Of the remaining students, in 2008 one student didn't register for math class and decided to take the Calculus class in spring 2010. In fall 2008, three students didn't register for any mathematics class but they already earned the credit for the pre-calculus class.

Table 4
Outcomes in the two groups for Calculus II

Group	Outcome					Avg. Performance	total
	A	B	C	D	F		
2008	1(50%)	None	1(50%)	None	None	3.0	2
2009	2(100%)	None	None	None	None	4.0	2
total							4

During the program's first year, participants were able to start with a higher mathematics level and earn six college credits. Fourteen out of twenty two students finished calculus on the 2008 fall semester; in addition two students started with higher mathematics level. The overall mean GPA was 2.8. In tracking the program first participants on their second year it was found that three students transferred to a non-STEM discipline, one student transferred to another STEM discipline, and two left the university. Of the remaining 17 students, their overall mean GPA for fall 2009 semester was 2.95.

In the fall of 2009, one participant transferred into a non-STEM major and another one transferred to a different institution. Thus, they were not counted in this paper's results. The mean GPA for fall semester was 2.97 for students who retained in their STEM majors and registered for the spring semester by the time data was collected (18 students).

From an optimistic point of view, sixteen out of nineteen participants of the 2009 were able to pass their mathematics class on the fall semester. In 2008, students showed a good performance as well since twelve out of fourteen students who stayed in STEM majors (students who are registered for the spring of 2010 semester by the time that data was collected) were able to pass their mathematics class sequence.

A comparison between the 2009 STP cohort and non-STP students

A further comparison was conducted in this paper to understand the impact of the STP program on students' performance from another perspective. Since two of the STP participants either left VCU or switched into a non-STEM major, a control group of 20 students was matched based upon STP participants major, gender, and race/ethnicity. The summary of the demographics of the two groups are represented in table 5. The average cumulative GPA, for fall 2009, for the STP and non-STP students is 2.8 and 2.6, respectively.

Table 5
Summary of study the two groups

Characteristic	STP minority students	Non-STP minority students
Race/Ethnicity (#)		
African American	18	18
Hispanic American	2	2
American Indian	0	0
Gender (#)		
Male	8	8
Female	12	12

In this study, 6 STP participants took Algebra (Math 141) class during fall 2009. A proportion of 0.33(2 students) of subjects who had a B in the Math 141 course was observed. However, the control group, the non-STP participants, had only 4 out of 20 students take the class during fall 2009. None of them earned either an A or a B, see table 6.

Table 6
Outcomes in the two groups for Algebra

Group	Outcome				Average Performance	total
	A	B	C	D		
STP Students	None	2(33.3%)	1(16.7%)	3(50%)	1.8	6
non-STP Students	None	None	2(50%)	2(50%)	1.5	4
total						10

As for the pre-calculus (Math 151) class, 4 STP students took the class compared to 11 from the control group. The number of students who had an A in the class is 3 for the control group while none for the STP group had an A, see table 7.

Table 7
Outcomes in the two groups for Precalculus

Group	Outcome					Average Performance	total
	A	B	C	D	F		
STP Students	None	2(60%)	1(20%)	None	1(20%)	2.0	4
non-STP Students	3(27.3%)	2(18.2%)	4(36.4%)	1(0.1%)	1(0.1%)	2.5	11
total							15

Seven STP participants took calculus (Math 200) class during fall 2009. A proportion of 0.86(6 students) of subjects who passed the course with a C or better was observed. However, the control group, the non-STP participants, had only 3 students took the class during fall 2009. All of them earned a B or better, see table 8.

Table 8
Outcomes in the two groups for Calculus

Group	Outcome					Average Performance	total
	A	B	C	D	F		
STP Students	2(28.6%)	3(42.8%)	None	None	1(14.3%)	2.8	6
non-STP Students	2(66.7%)	1(33.3%)	None	None	None	3.7	3
total							10

Two students in both groups were qualified for advanced mathematics class on the fall of 2009 and two of the STP group didn't register for any mathematics classes.

Discussion and Conclusion

Overall, the summer transition program is considered an effective method for improving academic preparation, in general, and mathematical accomplishment, in specific, for under-represented minority students in STEM disciplines. The program created a supportive environment and familiarizes students with what to expect on the upcoming academic year. Thus, students who didn't perform well on their mathematics preparation class during the program because of the new environment or unexpected type of questions had a good opportunity to overcome their difficulties and move forward with their peers on fall semester.

From another perspective, students who performed well in their mathematics class had a good preparation in math prior participation in the program. The same thing goes for the fall semester

and STP. If students are well prepared academically and had a good experience on what to expect in college once the semester started, it will affect their performance positively.

The program proved the importance of motivating students and increasing the commitment to academic excellence. In 2008, we noticed that the STP students worked harder to be placed into pre-calculus or higher in order to be eligible to participate in the program. They also earned six college credits and another three credits by skipping the algebra course. In observing our results from both years, we believe that the controlled environment in which the 2008 students lived was a significant factor contributing to the performance during the program. They lived together, studied together, and attended the same classes the whole day. Not only this, but also they had supervision and advice even if they did not ask for it. This impacted their performance in the pre-calculus course and kept them motivated to earn a high GPA to start with in the upcoming academic year. As a result, we decided to establish a Living Learning Community for the 2010 STP participants. Thus, we can make sure that our STP controlled environment will be extended to the larger VCU community and we can observe if it will work to keep the students on track with a larger community and additional distractions.

As for 2009 participants, participants' mathematics performance on fall 2009 varied based upon participants' mathematics placement test and mathematics performance during the program. Students who were placed into calculus or higher performed well in their first mathematics course in college. Those students performed well in the preparation summer course as well. As for students who were placed into pre-calculus or algebra, their performance on fall 2009 was comparable to their performance during the summer program. It was a challenge for algebra students to be in a pre-calculus course and they performed poorly during the program. In comparing the STP and non-STP groups for the year of 2009, the performance of STP students was not better compared to the control group. The algebra students' performance, from both groups, was not as good as students who placed into higher level. Due to the small sample size in this study we can not draw definitive conclusion, but must use this data to continuously improve the program.

Either taking the pre-calculus for credit or just having a pre-calculus preparation course, we believe it is still playing an important role in improving STP participants' academic success and retention in the long run. Choosing what works to ensure an improvement depends on the targeted group and major goals of the program. From the interpreted outcomes of the program in 2008 and 2009 and comparing them with non-STP participants, it was noticed that the participants' performance and the benefits they have gained were better in 2008. Students were qualified for the pre-calculus class; they had a good mathematical knowledge compared to other students in lower levels; and they were more enthusiastic to get good grades since they were taking the course for credit. Students who placed into algebra represent a good proportion of the overall population of minority students in STEM disciplines. Thus, the program targeted group of students who are not only placed into pre-calculus or higher, but also who placed into algebra as well. It is also necessary to focus on participants' differences and enhance their individual points of weaknesses in their mathematical skills.

Finally, the program not only provided a supportive environment for its participant and impacted their mathematical performance, but also it provided an opportunity to identify and improve the study skills they need to succeed in their freshmen year. As for participants' accomplishments in

their first mathematics class in the fall semester, there was no significant improvement, but there was some improvement on the overall performance.

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