

Developmental Student Success in Courses from College Algebra to Calculus

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Abstract. In 2007 the Department of Mathematics at West Virginia University began implementing a placement-based process designed to identify at-risk students entering mathematics courses at the College Algebra and Calculus levels. Major changes in our placement testing process and the resulting interventions for at-risk students were first put in place in the fall of 2008. The result of this implementation is a process that places students into a remedial PreCollege Algebra workshop, three different formats of College Algebra, and two formats of Calculus I. In the lowest level of this process we seek to intervene with students who traditionally perform very poorly in University level classes by offering a self-paced remediation that covers concepts from fractional and integer arithmetic, beginning function theory and basic Algebra. This program is delivered in the MyLabsPlus course management system using portions of the Martin-Gay *Intermediate Algebra* text. In the current work we will outline the basics of this remedial program and present data confirming the efficacy of this intervention.

1. Introduction

In 2007 the Department of Mathematics at West Virginia University began implementing a placement-based process designed to identify at-risk students entering mathematics courses at the College Algebra and Calculus levels. The placement test is delivered using the MapleTA online testing system and the content is based on the Mathematical Association of America (MAA) Placement Test question bank for that testing server. The test is formatted in two parts, the first of which covers Basic Algebra and consists of 25 multiple choice questions in that content area. Students must get at least 10 of these correct in order to place into a College Algebra course. They may place into a 3-day per week version of College Algebra (126C) that moves quickly and is intended for students whose long-term goal is Calculus, or they may place into four day per week (126B) or five day per week (126A) versions with supplemental instruction time intended for weaker students.

The second part of the test covers Calculus Readiness and again consists of 25 multiple choice questions in that content area. Students may place into our main one-semester Calculus I with very high scores, or they may place into either our applied Calculus or a two-semester Calculus 1 equivalent with lower scores.

Students are allowed to take the placement exam twice and just over 22,000 students have been placed into a math class (remedial non-credit or credit earning)

using this process since implementation in the fall of 2008. The following table shows the results of this testing process.

Course Placement	N	Percentage
126A	1910	8.50%
126B	3459	15.39%
126C	3946	17.55%
150/153	3758	16.72%
155	2943	13.09%
Workshop	6465	28.76%
Total	22481	

Figure 1 Numbers & Percentages of Placed Students by Course

Approximately 29% of our students place below College Algebra. As indicated in the table above, this translates into over 1000 students per year who need remediation before they can enter College Algebra. With no local community College to offer remedial mathematics courses, the WVU Department of Mathematics has developed a non-credit course to address deficiencies in the mathematical background of these incoming students. These are the students who score less than 10 out of 25 on part 1 of the placement exam (Basic Algebra) and enroll in the non-credit bearing remediation course referred to as the Pre-College Algebra Workshop which is described below.

2. The Pre-College Algebra Workshop

Remediation for students placing below College Algebra takes the form of a fifteen-week non-credit bearing course that requires students to meet with instructors for three hours per week and attend a tutoring lab environment one hour per week. The class is self-paced and students must engage in the process to be successful. The instructor helps facilitate learning, but does not lecture. They will offer explanations of course material frequently and assist with homework and practice problems as well as review exams with students on an individual basis. Instructors closely track student progress and intervene when students begin to show signs of difficulty such as not making adequate progress or simply not attending regularly.

Students are assigned homework quizzes (HWQs) covering several chapters of material in the Martin-Gay *Intermediate Algebra* text as implemented in MyLabsPlus. These HWQs lead to an exam for each chapter. Students must demonstrate mastery on each set of HWQs along with at least 80% mastery on each exam. Students are allowed three attempts on each exam before they must redo the quizzes. Once they complete each chapter exam, they must pass a comprehensive final exam with at least 70% mastery. They have three attempts at this exam as well.

The content covered in the Pre-College Algebra Workshop begins with basic arithmetic and includes

- Arithmetic and Order of Operations
- Solving Linear Equations and Applications
- Graphing Lines by Plotting Points
- Polynomials
- Factoring
- Rational Expressions
- Radical Expressions

Once students have passed the final they are given a score of 14 on the placement test. This overrides their previous score and allows them to sign up for 3, 4, or 5 day College Algebra but is not high enough to place into higher math courses. Occasionally, some students will use their second placement test attempt while still enrolled in the Pre-College Algebra workshop if they feel like their basic Algebra skills have strengthened enough during their time in the workshop course to improve their placement score enough to place them into a College Algebra course. There are also many students do not finish the Pre-College Algebra Workshop in one semester. These students are allowed to register for the workshop course during the following semester and simply pick up where they left off the previous semester.

It has been observed by several instructors of College Algebra that the students who do complete the Pre-College Algebra workshop have a stronger grasp of Algebraic skills than those who place directly into College Algebra via the placement exam. In the current work we attempt to verify this anecdotal information statistically by analyzing student performance relative to a number of criteria including their path of entry into College Algebra and other mathematics courses.

3. Entry Paths and Student Performance

Students may enter College Algebra at WVU in three ways: placement via our placement test, transfer of credit for a prerequisite course at another institution, or successful completion of our Pre-College Algebra workshop. In the beginning of this process a few students gained entry using SAT/ACT score placement as the old system was phased out.

Students who completed the Pre-College Algebra workshop were identified and tracked into College Algebra from Fall 2008 to Fall 2011. Student demographic data was analyzed to determine what path other students used to gain entry into a College Algebra course and the success rates were analyzed with grades of A, B, or C considered Success, grades of D or F considered Failure, and withdrawal grades of W considered separately. . As shown in the table below, success rates for the Pre-College Algebra workshop students who completed College Algebra successfully surpassed the success rates of other students (who successfully completed College

Algebra) by 4.4%. This data covers all three versions of our College Algebra (126A, B, & C).

Grades	All Students	Direct Placement into College Algebra (No Workshop)	Workshop - Placement Retake	Workshop Completion
Percent with A/B/C	61.6%	54.3%	55.0%	66.0%
Percent Withdrawal	14.1%	18.3%	16.0%	13.5%
Percent with A	12.0%	11.1%	2.7%	9.8%

Figure 2 Workshop Student Performance - All College Algebras

Upon closer inspection, workshop students who enter our three and four day College Algebra versions perform as well as the general population once remediated as indicated in the following table.

Grades	All Students	Direct Placement into 126B & 126C (No Workshop)	Workshop- Placement Retake	Workshop Completion
Percent A/B/C	63.3%	62.1%	55.0%	62.4%
Percent with W	13.0%	12.9%	16.0%	15.9%
Percent with A	11.8%	10.7%	0.8%	5.1%

Figure 3 Workshop Student Performance in 126B/C

However, in our five day College Algebra course, amongst the weaker students entering that course band (via direct placement), students who complete the Pre-College Algebra Workshop perform substantially better than their peers.

Grades	All Students	Direct Placement into 126A (No Workshop)	Workshop- Placement Retake	Workshop Completion
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Percent A/B/C	55.1%	53.1%	52.7%	77.7%
Percent with W	18.4%	24.5%	23.6%	5.8%
Percent with A	13.1%	12.4%	7.3%	24.8%

Figure 4 Workshop Student Performance in Math 126A

Indeed, 22% more students who successfully complete the workshop succeed in 126A (77.7% success) than the general population entering by placement or other prerequisite (55.1%). These outcomes are encouraging but analysis of performance in subsequent courses indicates that the Pre-College Algebra Workshop students continue this trend into other coursework.

4. Subsequent Courses

The background of students whose placement test scores put them in our Pre-College Algebra Workshop does not typically lead them into STEM majors and as a result, not many of them proceed out of College Algebra into higher level mathematics courses. As indicated below, more than half of these students stop their formal mathematical education at College Algebra. A substantial number, however, do complete our applied Calculus, and approximately 5% have a final attempted course during this time period of our first term Calculus I, and another 4.44% ended their mathematics coursework in either Calculus II, III or Differential Equations.

Final Attempted Math Course	Percentage
College Algebra	53.55%
Applied Calculus	14.97%
Trigonometry	14.21%
Calculus I	5.08%
Liberal Arts Math	4.95%
Calculus II+	4.44%
Elementary Education Math	1.90%

Figure 5 Students Completing Pre-College Algebra Workshop Final Math Course

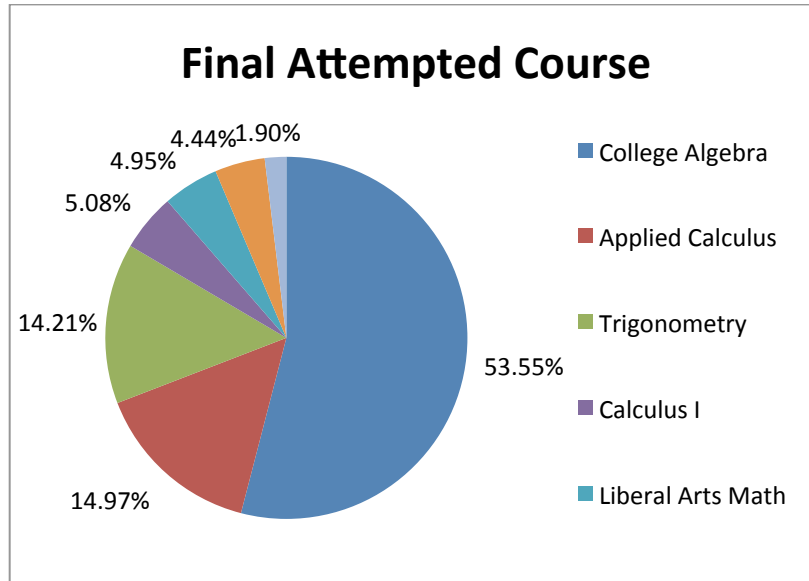


Figure 6 Proportion of Students Entering Subsequent Math Classes

We tracked the Pre-College Algebra Workshop students into these subsequent courses and analyzed their outcomes.

5. Calculus Performance of Workshop Students

In our applied Calculus course, students who completed the Pre-College Algebra Workshop successfully were then subsequently successful in applied Calculus after completing College Algebra over 90% of the time. This can be compared with the general population success rate of 77.9%. Moreover, students who completed the workshop were more than four times less likely to withdraw from Applied Calculus than the general population.

Grades	All Students	Direct Placement into College Algebra (No Workshop)	Direct Placement into Applied Calculus (No Workshop)	Workshop Completion
Percent A/B/C	77.9%	78.9%	80.7%	90.2%
Percent with W	9.1%	8.3%	6.7%	2.2%
Percent with A	34.1%	30.5%	38.9%	30.4%

Figure 7 Success Rates for Students in Applied Calculus

The significance of this outcome can be seen most clearly by a comparison of the backgrounds of students in the Applied Calculus course. We performed an analysis of the student demographics and observed that the average SAT and ACT math scores for successful students in Applied Calculus who had completed the workshop were in a range (20-21 ACT, 480 SAT) indicative of a low probability of success in any mathematics course, while the successful students from the general population of Applied Calculus had substantially higher average scores consistent with Calculus I track students (23 ACT, 555 SAT).

		All Students	Entry from College Algebra (No Workshop)	Applied Calculus Placement	Entry from Workshop
ACT Math Averages	Students with an A	24.13	23.18	24.88	19.9
	Students with A/B/C	23.14 N=1273	22.14 N=539	24.55 N=335	19.84 N=64
SAT Math Averages	Students with an A	555.83	537.72	576.99	509.57
	Students with A/B/C	540.28 N=1465	525.66 N=724	569.23 N=391	496.75 N=77

Figure 8 SAT and ACT Averages by Population in Applied Calculus

It is natural to wonder if this phenomenon extends to our mainstream Calculus I or two-semester Calculus I equivalent. For the mainstream Calculus I, Math 155, observed success rates were less than the general population. The relative number of students entering Calculus I who successfully completed the Pre-College Algebra Workshop was small and their success rate was approximately 44%, lower than that of their classmates in Calculus I by approximately 20%. . It was observed, however, that the student profile of these workshop completed students was again remarkable in comparison to the average student entering Math 155.

Grades	All Students	Direct Placement into College Algebra (No Workshop)	Direct Placement into Calculus I (No Workshop)	Workshop Completion
Percent A/B/C	65.0%	50.1%	75.0%	44.7%
Percent with W	15.5%	22.5%	10.3%	25.5%

Percent with A	22.0%	9.8%	27.4%	4.3%
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Figure 9 Student Success by Entry Path in Calculus I

		Entry from College Algebra (No Workshop)		Direct Placement into Calculus I	Entry from Workshop
	Grades	All Students			
ACT Math Average	Students with an A	28.85	23.76	28.72	N/A
	Students with A/B/C	26.82 N=1299	22.83 N=240	28.08 N=694	20.24 N=17
SAT Math Average	Students with an A	637.78	571.2	635.5	N/A
	Students with A/B/C	608.48 N=1234	538.97 N=204	624.83 N=696	480.71 N=14

Figure 10 SAT and ACT Averages by Population in Calculus I

In this data we observed that the Pre-College Algebra Workshop students who succeeded in Calculus I had significantly weaker backgrounds as evidenced by average ACT math scores of 20.24 and average SAT math scores of 480.71. These can be compared the more commonly observed averages of 26.8 and 608.48, respectively, among the successful students in the general population. This indicates that substantial remediation of the students ability had occurred but that there were areas, most likely trigonometry, in which they still struggled and consequently sometimes did not succeed in the traditional Calculus I course.

It is natural to ask how the population determined by this SAT/ACT profile fared in general in our Calculus sequence. This analysis and a similar study of our two-semester Calculus I equivalent are the subject of future work.

6. Long-term STEM Success

As indicated above, only 4.44% of students who completed the workshop enter courses above Calculus I. These students number around 50 over the four-year period being studied. This is partially due to the success rate of these students in Calculus I and needs to be address. Surprisingly, however, we find that these students succeed at almost the same rate as the general population in these higher level mathematics courses (Calculus II and above).

Grades	All Students	Workshop Completion
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Percent A/B/C	73.9%	76.0%
Percent with W	9.8%	8.0%
Percent with A	26.3%	24.0%

Figure 11 Student Outcomes in Courses Beyond Calculus I

Moreover, their withdrawal rate is also almost the same, and they receive a grade of A at almost the same rate. This is an encouraging result for these students, and our goal over the next four years will be to broaden this result.

7. Conclusions and Future Work

Our data analysis indicates somewhat conclusively that for the weakest of our students the PreCollege Algebra Workshop as it is currently delivered performs exceedingly well. Students are remediated in a fashion that allows them to be successful in the target 5-day College Algebra course at a rate that is substantially higher than the general population. Moreover, we observed that the training and skills developed during the workshop carryover strongly into our Applied Calculus course.

Many questions and tasks remain, including

- A redesign of the workshop to incorporate more sustained in-class work and contact time
- A similar study of the effect of workshop on students entering our two-semester Calculus I equivalent though this population will be small
- A comparison of the performance of students with similar backgrounds coming in via transfer or other paths to students completing workshop in subsequent courses
- The possible development of other workshop alternatives including short-term remediation courses for stronger students and a trigonometry focused workshop type course

Overall, we feel that we have found a beginning point for addressing the large number of at-risk students entering our university each year and we will be able to build a long term process that assists any student who is willing to engage in that process in being successful.

References

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