

A Longitudinal Study of Students in a Dual-Enrollment Mathematics Program: A Focus on Preparation for Calculus

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Abstract This is a continuation of a longitudinal study implemented to determine if students enrolled in a dual-credit mathematics program are sufficiently prepared for success in first semester calculus. In the current cycle, thirty high school students enrolled in a year-long sequence of two university mathematics courses were followed through their first-year, on-campus calculus course. Course grades, interviews and surveys were used to determine factors that influence student success. The dual-enrollment courses in this study meet the same level of rigor as the courses taught to traditional students at the partner post-secondary institution. Results indicate that students who complete dual-credit algebra and trigonometry courses through an outreach program are as least as well prepared for Calculus I as those who take those courses on campus. However, over the course of this longitudinal study it has been found that prior experience in calculus is also an important factor to consider in student success.

Keywords: *calculus, dual-credit, early-enrollment, first year courses, mathematics*

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1. Introduction

Dual enrollment was mentioned in the 2014 State of the Union address with respect to promising partnerships between high schools and colleges (Obama, 2014). In 2010-11, about 82 percent of U.S. public high schools reported that students were enrolled in a dual-credit course [1]. In fact, dual or concurrent enrollment credits are offered in every state and the District of Columbia, with the number of U.S. public high schools offering dual-enrollment programs growing [18]. Given that in the U.S. only 65.9 percent of people who had graduated from high school in the spring of 2013 had enrolled directly into college, the lowest figure in a decade, it is no wonder that dual enrollment is getting more attention. This growing interest in dual-credit enrollment was highlighted by Michigan News (2013), which reported an awarded \$2 million grant from the U.S. Department of Education to launch a five-year study on the impact of a new dual-credit policy in Tennessee. Early entry courses are typically identified as higher education courses taken by high school students who have enrolled at a college or university prior to high school graduation. Early entry course grades appear on the college/university transcript and are used toward a college degree. A dual-credit course, also known as a dual-enrollment or concurrent enrollment

course, is a type of early enrollment course such that a high school student earns credit toward a college degree, and simultaneously earns credit toward high school graduation.

The Community College Research Center at Columbia University's Teacher College studied a three-year dual-enrollment program developed for low-income students and English-learner students who were struggling academically. They found that the participating students stayed in college and earned more credits than similar non-participating students in their district (Rodriguez, Edwards, & Belfield, 2012). Zinth [17] reports similar benefits of dual-enrollment programs including improved college completion rates particularly for minority and low-income students.

West Virginia is the only state to be entirely contained in Appalachia. Typically, students from low-income, rural high schools have the lowest college-going-rate. They are less likely to enroll in college than students from low-income, high-minority urban schools. In addition, national data suggest that rural students are significantly more likely than their peers in both city and suburban high schools to access dual enrollment which is primarily done through distance learning. However, critics raise concerns that these students struggle with elevated expectations, the faster pace of a post-secondary course, and broadband issues [18]. Koicich [5] reports that only 64 percent of rural students pursue post-secondary education, compared

to nearly 70 percent who live in metropolitan areas. Nationally the enrollment rate is about 66 percent. Koicich found that of those rural students who attended college, 47 percent chose a two-year institution. In addition, he found that students at low-income rural schools are less likely to attend college than their peers at high-income rural schools, and they are also less likely to persist to their second year of college. One suggestion given to improve completion rates for rural students was to strengthen relationships between high schools and colleges to help ease the transition [5].

Can struggles by rural students with respect to college matriculation and retention be overcome to produce long-term, positive results? Some findings from a study of online courses offered by community colleges may offer some hope. According to data collected from 122 community colleges in California, students were less likely to complete online courses than traditional courses, and those who did complete their online course were less likely to do so with passing grades compared to those in traditional courses. Only 60 percent of students achieved passing grades in online courses versus 70.6 percent in face-to-face courses. However, when studying long-term impact, measured by the likelihood of a student earning a degree or transferring to a four-year college, those who combined traditional and online courses were more successful than those who took only face-to-face courses [8]. Can a similar finding be made for students who combine enrollment in dual credit and traditional courses and struggle in the beginning?

Zinth [18] reports that among other things, model dual-credit courses meet the same level of rigor as the course taught to traditional students at the partner post-secondary institution and offer transferability of the credit, at least within the state being offered. Participating students in such courses are more likely to meet college-readiness benchmarks, more likely to enter college and to enter shortly after high school graduation, have a lower likelihood of placement into remedial mathematics and English, have higher first-year and second-year retention rates, and have higher four- and six-year college completion rates. Of students who complete within six years, those who participated in dual enrollment courses also have a shorter average time to bachelor's degree completion compared to those who did not.

Dual-enrollment courses are offered to students who are in transition from high school to college. Those are the same students who often struggle with mathematics and English. Yet, it is not unusual for mathematics courses to be listed among the options for dual-credit offerings. This issue was addressed in the 2013-14 Remedial Placement and Enrollment Report presented to the Legislative Committee on Education by the Nevada System of Higher Education. At the University of Las Vegas, 50.3 percent of students took college-level mathematics in their first year of college; the graduation rate of those students was 49.1 percent. For the 49.7 percent who did not take a college-level math course in the first year, the graduation rate was 27.2 percent. Similar results were reported for other colleges in the state [16]. It seems that passing mathematics in the first semester of college may be an important factor to consider when predicting college completion. Can taking a mathematics course as a dual-enrollment course yield the same impact?

2. Review of Literature

Included in the goals of any dual-credit course should be that the course meets the same level of rigor as the post-secondary partner course and that enrolled students are at least as well prepared for the next course as those who have taken it traditionally on campus [2,18]. An example of a successful, collaborative program offering college-level courses to high school students is offered at a large northeastern university. Measures are taken to assure that the level of rigor is the same as the courses taught to traditional students at the partner post-secondary institution. The program courses are offered in a blended learning environment where work is completed both on-line and face-to-face. Information about the development of the project can be found in earlier publications [9,10,11]. Since Fall 2000, approximately 4,600 high school students have completed College Algebra and since Spring 2003, approximately 2,500 high school students have completed College Trigonometry. A newly developed sequence of courses equivalent to a one-semester course of Calculus I has been offered to approximately 125 high school students in its pilot phase. From the first offering of College Algebra in the program, course grades indicate that our early-enrollment or dual-credit high school students seemingly outperform their on-campus peers. Typically the DFW rate for an dual-credit course in the project is less than 10%. The DFW rate is the percentage of students earning a "D", "F" or Withdrawing from a course. The grading system in this study uses the following scheme: A – excellent (given only to students of superior ability and attainment), B – good (given only to students who are well above average, but not in the highest group), C – fair (average for undergraduate students), D – poor but passing (cannot be counted for graduate credit or in the case of this study for enrollment into the next mathematics course), F – failure, and W – withdrawal from a course before the date specified in the University Calendar.

Table 1 shows DFW rates for students enrolled in Calculus I at our institution. Rates are given for two groups, former dual-credit students and all students enrolled in the fall offering of the 4-credit course. It is noteworthy that in 2008 the placement exam used for Calculus I was changed and in 2010 the section of the placement exam used for entry into Calculus I was modified. There are typically about 700 - 800 students enrolled in on-campus Calculus I in any given fall semester. It should be cautioned that in this comparison, the number of dual-credit students followed through is low and that in most cases the difference in percentage for the dual-credit columns can be changed by adjusting the performance of only a few students. In addition, there are two different versions of Calculus I at our institution, Engineering and Non-Engineering, and differences in student success in each of these versions will be explored.

The literature suggests that given the trend that so many students are now taking calculus as a high school course, it is recommended for universities to rethink the structure of their Calculus I and Calculus II courses [3]. Should there be different Calculus I experiences for students depending on their prior experiences in calculus? Is it possible that the year-long version of Calculus I, originally established at our institution for students with

lower placement scores, is a better alternative for all students entering with no previous calculus experience?

Table 1. DFW Rates for Students in Calculus I Courses

Semester	DFW rate early entry students	DFW rate all students
F05	44.4% = (12/27)	47.7%
F06	62.9% = (17/27)	57%
F07	31.25% = (5/16)	55.3%
F08	40.9% = (9/22)	35.5%
F09	27% = (8/30)	35%
F10	46% = (18/39)	35%
F11	50% = (16/32)	37%
F12	55% = (27/49)	45%
F13	37% = (11/30)	39%

The motivation for this continuing study is a trend of a higher percentage of DFW rates for dual-credit students when enrolled in their first-semester, on-campus Calculus I course. Other selected information and background information for this longitudinal study can be found in earlier publications [12,13]. The driving question of this study is, "Are students who complete a dual-enrollment mathematics program of courses at least as well prepared for calculus for the next course as those who have taken it traditionally on campus?"

3. Method

In order to better understand the challenges that face first-semester calculus students entering from the early-enrollment program, quantitative algebra, trigonometry and calculus course data were collected. Students who experienced varying levels of success in a first-semester calculus course were then interviewed in order to contextualize and expand upon the quantitative findings. The interviews were designed to provide insight into the attitudes of students as they relate to success in calculus. Follow-up surveys were then administered to all former dual-credit students in order to capture a more global perspective of their attitudes.

3.1. Participants

Quantitative data were collected from 30 students (70% male) enrolled in Calculus 1 (Math 155) during the Fall 2013 semester at a northeastern university in the United States. The students all participated in an early-enrollment project as high school seniors and upon entry into the project had at least a 3.0 high school grade point average (GPA) and had earned a C or better in Algebra I, II and Geometry. As high school seniors, they completed WvEB Algebra (college algebra) and WvEB Trig (college trigonometry) with the grade of a C or better. All students were invited to participate in the interview process; three agreed. Of the 30 students, 10 completed the survey, yielding a 30% response rate.

3.2. Survey

The project coordinator and researchers used the analysis of the initial cycle of interviews and a review of the literature to design a 9-item survey. The survey was

given online and was anonymous. In addition to collecting some basic background information, questions explored students' feelings about their pre-requisite content knowledge, self-confidence with respect to doing mathematics, enjoyment of doing mathematics, and feelings of relevance of mathematics. There was also an opportunity for students to discuss the instruction and organization associated with the calculus course. One question asked students if the instructor or student has more impact on the successful completion of Calculus I (Math 155).

3.3. Procedure

All students in the study completed the four-credit calculus course, Math 155, in the Fall 2013 semester. Student interviews were conducted during the Spring 2014 semester so that students could reflect on their performance after completing (or withdrawing from) the course. The purpose of the interviews was to contextualize and expand on quantitative performance and attitude data, ideally leading to a deeper understanding of students' attitudes, successes, and challenges in calculus.

The student interviews were open-ended, semi-structured and audio taped with questions that focused on attitude and success in calculus. Examples of questions that students were asked include: 1) Do you feel that you were appropriately placed to enroll in calculus? Why or why not? and 2) What indicators led you to believe that you were ready for the course? There was a single interviewer for all three students.

Following verbatim transcription of all audio recordings, a coder independently analyzed student transcripts, searching for key words and phrases using in vivo open coding techniques [15] to identify themes that emerged for the group. Following initial coding of student data, collaborating researchers analyzed transcripts and compared their analysis to the initial coder's work. Any discrepancies were resolved by discussing and re-evaluating transcript data until consensus was reached. Finally, the coder applied axial coding [15] to analyze the categories that emerged.

In the Spring 2014 semester, all students were asked to complete an anonymous, online, follow-up survey. The results from most survey questions were quantifiable, and in the case of open-ended questions, an analysis was performed using techniques similar to those applied during the interview analysis.

4. Results

4.1. Student Interviews

Student interview data provided richer context and student voices to supplement quantitative performance. Three students were interviewed. All students completed dual-credit Algebra and Trigonometry courses in high school the previous year. Student 1 was majoring in Secondary Mathematics Education after changing from Finance. Student 1 completed non-Engineering Calculus with the grade of "C". Student 2 completed non-Engineering Calculus with the grade of a "B" and was majoring in Mathematics Education and History. Student 3 completed Engineering Calculus with an "A" and was

majoring in Civil Engineering. Student 3 took AP Calculus, but did not pass the AP exam.

Four themes related to success in calculus were identified during the analysis of student interviews. Those themes were Prior Calculus, Dual-enrollment Preparation, Self-Regulation/Self Discipline and Instructor Qualities.

Prior calculus. Two of the three students did not have calculus in high school, but all three said that it would help a student succeed in calculus their Freshman year if they took calculus in high school. All three students said that it helps to have seen a topic beforehand and one felt that he/she was at a disadvantage because he/she had not taken it in high school and that having calculus in high school would boost confidence. For example, one student said, "[having calculus in high school] really helped. I didn't remember everything that I was taught, but at least I'd seen it before, and when it was re-taught, I really picked up on it in a better way." In addition, two students blamed their difficulties with specific topics on their lack of exposure to calculus while in high school. One student responded that he thought he might experience trouble with series and sequences, "I hadn't seen anything for the series and sequences before, we didn't get to that in my AP Calculus class...it is hard to pick up on new stuff in a lecture when the concept is something I've never seen before."

Dual-enrollment preparation. All three students said that the dual-enrollment courses helped prepare them for their college courses and made them more confident as they better knew what to expect. They also all said that the courses helped their transition and specifically identified becoming familiar with eCampus/web tools as a definite perk. "I really liked, in high school, learning how to navigate eCampus and everything...because when you come here, no one is here to teach you how to do that stuff, but my high school instructor taught us how to navigate and all that, check grades, and everything." In addition, one student still felt that pace was faster on campus, another student said that the dual-credit course prepared her/him for learning "something new every day". One student said that WvEB was good because you could complete 6 credits of math in a smaller, less intimidating setting before starting college.

Self-regulation/self-discipline. All three students self proclaimed to be "good students" and felt that it was their responsibility to adjust to pace, seek help, and identify difficult topics (when and what to study). One student said, "when I knew I didn't understand something I'd go home and study it. If I still didn't understand, I would ask [my teacher]." Two of the three students used video resources to help learn the material and expressed importance in learning concepts to better understand the material. They also advised future students to establish a routine, keep a planner (to stay on task- and keep up with material). "Stay on pace, there is no one there to tell you to do your homework every night or anything. Don't go through and do all your homework before your test that's the next day or something. Stay on pace for yourself and get help if you need it."

Instructor qualities. Two of the students discussed instructor qualities and identified previous instructors and being "good teachers". One student advocated seeking help from the Math Learning Center because it was less

intimidating asking for help from students than instructors. The two students that identified themselves as having good instructors included the following qualities: available/approachable, not intimidating, gave lots of different examples, and "went over everything so you did not have to feel uncomfortable asking questions."

4.2. Survey Results

Ten of the thirty invited students completed the anonymous survey. Not all students responded to all questions. Four of the students were enrolled in the Engineering Calculus sections; five of the students were enrolled in the Non-Engineering Calculus sections. One student did not identify the type of section. None of the students reported having a calculus course in high school, though one completed Pre-Calculus. None of the students said that they withdrew from the Calculus I course in the fall semester. Two were re-enrolled, one each in Engineering and Non-Engineering Calculus I, at the time of the survey meaning they earned a "D" or "F" in the course the first time it was taken. One of the two re-enrolled students attributed poor performance the first time to an unexpected pregnancy.

When asked if they were aware that there was a year-long option for Calculus I, only five of the nine responding students responded with a yes. Of the six students responding to the question asking if they felt that either the Business Calculus or year-long Calculus with Pre-calculus course would have been a better option, four students said no, one said maybe and one said yes. The student who felt that the year-long course would be a better option said that he/she had never taken a calculus course and found it extremely difficult to comprehend a lot of the topics. Items discussed that would help students do well in calculus were working problems, seeking help, going to office hours, forming study groups and studying, doing the homework, and reviewing for tests. One student felt that having a background in calculus would be helpful. When asked who has more impact on the successful completion of Calculus I, the teacher or the student, four chose the teacher and five chose the student. One student did not respond. Reasons for the choice were interesting. Though a choice was made, two of the students thought that both the teacher and the student are responsible for the student to be successful. "It does not matter how good the instructor is if the student does not try. On the other hand I think the instructor has the ability to enhance or deter the students' skills in the mathematics."

4.3. Grade Distributions

In recent years, our University has implemented changes with respect to content, teaching methodology, and assessments in entry-level calculus courses. However, though both the Engineering and Non-Engineering sections of Calculus I feed into a common, coordinated Calculus II course, there are two coordinators for Calculus I. Table 2 shows DFW rates for students enrolled in each version of Calculus I. Rates are given for two groups, former dual-credit students (those passing both WvEB Algebra and WvEB Trigonometry the previous year) and all students enrolled in the fall offering of each 4-credit course.

Table 2. DFW Rates for Students in Calculus I

Semester	DFW rate dual credit students engineering	DFW rate all students engineering	DFW rate dual credit students non-engineering	DFW rate all students non-engineering
F12	81% = (17/21)	54%	36% = (10/28)	35%
F13	28.5% = (4/14)	43%	44% = (7/16)	32%

Table 3. DFW Rates for Students in First Semester Year-Long Calculus I

Semester	DFW rate dual credit students	DFW rate all students
F12	11.4% = (4/35)	41%
F13	15.9% = (7/44)	37%

Table 3 shows DFW rates for students enrolled in the first semester, year-long, Calculus I course at our institution. This course combines calculus and pre-calculus topics. Rates are given for two groups, former

dual-credit students and all students enrolled in the fall offering of the 4-credit course. There are approximately 400 students enrolled in the first semester on-campus, year-long course each year.

Table 4 shows DFW rates for students enrolled in the fall Calculus I course who took College Algebra and Trigonometry in the fall and spring semesters the previous year. Rates are given for two groups, former dual-credit students and on-campus students for each version of the 4-credit Calculus I course.

Table 4. DFW Rates for Students in Calculus I with Dual Credit and On-campus Pre-requisites

Semester	DFW rate dual credit students engineering	DFW rate on-campus students engineering	DFW rate dual credit students non-engineering	DFW rate on-campus students non-engineering
F12	81% = (17/21)	90% = (44/49)	36% = (10/28)	45% = (17/37)
F13	28.5% = (4/14)	63% = (5/8)	44% = (7/16)	43% = (12/28)

5. Discussion

The driving question of this study is, "Are students who complete a dual-enrollment mathematics program of courses at least as well prepared for calculus for the next course as those who have taken it traditionally on campus?" The motivation for this study is trend data indicating that dual-credit students at our institution might be experiencing higher-than-normal difficulties in their first on-campus Calculus I course. Students in the early-enrollment project must have at least a 3.0 overall high school GPA and a C or better in Algebra I, Algebra II and Geometry at the time of enrollment. Thus, students in the project have relatively good grades. The students in the early-enrollment project typically succeed in College Algebra and College Trigonometry courses, and while these courses are not among the traditional AP course offerings, they are considered advanced high school mathematics courses.

An analysis of the data suggests that although there is a recent trend of higher DFW rates in Calculus I for the dual-credit students, the trend may be changing. The dual-credit students' DFW rate of 37% in Fall 2013 was similar to the 39% for all students. However, it is noted that fewer dual-credit students are taking Calculus I in their first semester and more are taking the year-long Calculus course. The findings from a prior study [12] suggest that changes made to the placement test and cut-off scores used to place students into Calculus I create a "success gap" between students placed via the placement test and those placed using prerequisite courses. Dual-credit students who have successfully completed both algebra and trigonometry are able to enroll directly into Calculus I in their first semester, but due to the difficulties emerging in recent years, students are now advised to consider the year-long Calculus I course. Students taking that option are doing well when compared to their on-campus peers; but, only approximately one-half of the surveyed students

knew about that option. More must be done to get this information to the students.

When compared with on-campus students taking the same pre-requisite courses of algebra and trigonometry, the dual-credit students were found to have lower or similar DFW rates in both versions (Engineering and Non-Engineering) of Calculus I. An additional observation is that there are fewer on-campus students moving through the sequence of courses, algebra to trigonometry to calculus, than one might expect. Our university had not offered a pre-calculus course in several years. In the Fall 2013 semester, our university began, once again, to offer Pre-Calculus and students were longer able to enroll in algebra and trigonometry concurrently. It should be noted that this only changed placement criteria for courses before calculus.

Four themes related to success in calculus were identified during the analysis of student interviews. Those themes were Prior Calculus, Dual-enrollment Preparation, Self-Regulation/Self Discipline and Instructor Qualities. Recent findings in the literature leads us to believe that prior experience with calculus concepts is a factor that can influence student success in entry-level calculus [12,13]. In this study, all of the interviewed students and one of those surveyed felt that having exposure to calculus topics prior to taking the course would be helpful. In addition they all felt that the dual-enrollment courses of algebra and trigonometry helped prepare them for calculus. They reported that the dual-enrollment helped them with experience using the eCampus portal and prepared them for the pace of the course. Students were also prepared to manage their study habits and learning of the material. It is interesting that one survey question asked students if they felt that the instructor or the student had more impact on the successful completion of Calculus I and about half the students chose the teacher. Interviewed students characterized good teachers as available/approachable and not intimidating. They also said that good teachers provide lots of different examples and are willing to go over

everything so you do not have to feel uncomfortable asking questions.

6. Conclusion

It is the intent that findings in this study be used to improve student performance in Calculus I either directly or indirectly. The driving question of this study is, "Are students who complete a dual-enrollment mathematics program of courses at least as well prepared for calculus for the next course as those who have taken it traditionally on campus?"

The dual-enrollment courses in this study meet the same level of rigor as the courses taught to traditional students at the partner post-secondary institution [11]. Results indicate that students who complete dual-credit algebra and trigonometry courses are at least as well prepared for Calculus I as those who take those courses on campus. However, over the course of this longitudinal study, it has been found that prior experience in calculus is also an important factor to consider when evaluating student success. We suggest that there should be a different Calculus I experience for students depending on their prior experiences in calculus. In this study, the year-long version of Calculus I was a better course for many of the dual-credit students.

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