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Effectiveness of Developmental Mathematics Models on College Algebra

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Abstract

Higher education institutions must test and place undergraduates in appropriate developmental or college-level courses based on their academic ability. However, students required to take developmental courses risk postponing their graduation as well as incurring additional expenses. The purpose of this quasi-experimental quantitative study was to examine the effectiveness of two developmental mathematics models used in higher education. Comparative research questions were posed about differences in college algebra course completion at a Hispanic-Serving Institution. The difference in the proportion that completed college algebra was significantly greater for students enrolled in the co-requisite developmental mathematics model.

Introduction

The Texas Higher Education Coordinating Board (2015) launched their ambitious strategic plan entitled *60x30TX* with the objective to ensure that 60% of Texans between the ages of 25 and 34 attain a postsecondary credential by the year 2030. To realize the goals set in the *60x30TX* initiative, institutions must test and correctly place undergraduates in appropriate developmental or college-level courses based on students' academic ability (Texas Higher Education Coordinating Board, 2015).

Higher education institutions may address the need for developmental education by offering different course models with one being a traditional prerequisite model that requires students to enroll in a 3-hour/week, semester long course that is not credit-bearing towards an undergraduate degree program. Another course model is the co-requisite model which is multifaceted and includes supplemental instruction and one-on-one tutoring as well as technology-based interventions to provide additional academic support. Students enrolled in developmental education courses must earn a grade of CR (credit) to have the course considered successfully completed. Students are automatically placed back into developmental courses the following semester if they receive a grade of NC (no credit) unless the student has subsequently met the requirements of the Texas Success Initiative Assessment.

Records nationwide indicate that developmental mathematics courses consistently experience larger enrollments than developmental education courses for reading and writing (Gerlaugh et al., 2007). Researchers have also found that undergraduates who fail or withdraw from their first developmental mathematics course are more likely to withdraw from higher education altogether (Fike, D., & Fike, 2008).

This problem is twofold; financially, undergraduates who are placed into developmental courses, which do not contribute to their majors, incur added expense. Academically, developmental courses may also postpone students' graduation date (King et al., 2017). According to U.S. Department of Education data, remediation and non-completion cost undergraduates nationwide $1.3 billion in out-of-pocket expenses during the 2013-2014 academic year (Schak et al., 2017, p. 10).

The Texas Higher Education Coordinating Board found that for the Fall 2015 developmental mathematics cohort at one Hispanic Serving Institution (HSI) only 65.8% met the mathematics component of the TSIA obligations within two years (Texas Higher Education Coordinating Board, n.d., p. 3). The goal was to reduce developmental education barriers for millions of students through research based policy change. In 2017, Texas passed House Bill 2223. This required all public universities to institute co-requisite developmental models in 25% of their developmental coursework by 2018, 50% in 2019, and 75% in 2020 (Hartman, 2018, p.48).

In response, Texas colleges and universities established co-requisite laboratories in conjunction with introductory college-level mathematics lecture. The objective was to provide additional academic support as an alternative to traditional developmental mathematics courses. As a result, in lieu of offering Developmental Algebra, which is the prerequisite in the sequential developmental model, academic advisors place undergraduates in College Algebra courses with a co-requisite developmental model laboratory.

The purpose of this quasi-experimental quantitative study was to examine the effectiveness of the two developmental mathematics models offered at one Texas HSI. The two models consisted of one that had a co-requisite laboratory and one that was a traditional prerequisite model. Both must be taken sequentially with developmental coursework prior to taking college level mathematics to help undergraduates successfully complete introductory college level mathematics (College Algebra) and fulfill the general education requirements of their undergraduate program.

Effectiveness was measured by comparing College Algebra passing or failing grades received by two groups of undergraduates at one Texas HSI: one group took the course with a co-requisite laboratory or NCBM (Non-Course Competency-Based Mathematics) concurrently with the college-level Algebra while the second group of undergraduates who took the stand alone prerequisite Developmental Algebra, prior to the college level Algebra, from Fall 2015 through Spring 2018, but were not enrolled in the co-requisite laboratory. The Non-Course Competency-Based Developmental Education Interventions is the corequisite model that provides interventions such as tutoring, supplemental instruction or laboratories that is overseen by an instructor to identifies undergraduates' weaknesses in order to prepare them for college-level work (Texas Administrative Code, Rule §4.53).

Though admission to a public higher education institution cannot be granted based solely on placement tests scores in the state of Texas, they are a useful tool for admission counselors or academic advisor to utilize in appropriate placement of undergraduate students in college-level or developmental courses (Texas Higher Education Coordinating Board, 2014). Academic advisors are encouraged to engage in a more complex, holistic method to determine appropriate placement based on the individual needs of each undergraduate student which may include prior coursework in high school, advance placement test scores, dual enrollment credit as well as motivation, commitment and attitude (Texas Higher Education Coordinating Board, 2014).

The HSI employed a holistic approach to course placement starting with the TSIA as well as the students' SAT and/or ACT test scores along with their high school GPA and grades in Algebra I and II to determine eligibility for taking college level mathematics. This aligns with the belief of both researchers and administrators that results of standardized tests are not necessarily accurate predictors of academic success in higher education (Atuahene & Russell, 2016). Incoming students attending the higher education institution that is the setting of this study who attain an SAT score of 480 - 530 to lower are placed in the stand-alone developmental course, Developmental Algebra (MATH 0302), which did not have a supporting laboratory corequisite. Consequently, students whose SAT scores fall between 530 and 550 are placed in the lower college-level mathematics course (MATH 1314) with a corequisite laboratory (NCBM 0101) for additional support.

Review of Literature

Traditionally, developmental mathematics has been offered with an emphasis on instruction in algebraic content. Researchers have consistently found that placement into a traditional developmental mathematics model of progressive courses can predispose undergraduates to failure (Boatman & Long, 2018; Grubb, 1999; Grubb & Gabriner, 2013; Melguizo et al., 2008). Undergraduates who are placed into developmental mathematics incur additional financial costs as well as delays in graduation, and this often leaves them discouraged to the point of being unable or unwilling to persevere toward degree completion (Melguizo et al., 2008). The courses themselves are usually lecture-based and often utilize archaic methodologies and assessments such as "skill and drill" with little or no supplemental academic support, and results in undergraduates withdrawing from the course. (Grubb, 1999; Grubb & Gabriner, 2013).

Researchers Fong et al. (2015) took into consideration the attributes of students placed into a traditional developmental mathematics model predisposition to failure when they embarked on their study. They tracked undergraduates' progression through developmental math sequences as defined by completion and passing each course of the sequence. The researchers employed a stepwise logistic regression model to discover that the largest variance was explained by individual characteristics, and identified specific factors associated with higher number of attempts (e.g. ethnicity) and passing rates (e.g. class size) in the developmental mathematics course sequence. Based on the results of their study, Fong et al. recommended that higher education institutions implement policies to decrease the number of course attempts in an effort to increase passing rates of prerequisite courses.

In keeping with Fong et al. (2015) recommendations to adopt strategies to increase passing rates of the prerequisite courses; Acosta et al. (2016) studied the effect of delivery modality, student overall GPA, as well as the time-lapsed between high school and entry into higher education as effects on students enrolled in developmental math and their subsequent success in college-level math. Compiling 4 years of historical data to review results of developmental mathematics completion as well as completion of college-level mathematics, the researchers conducting this ex-post facto study found that there was a 3.64 times greater chance of a student completing college level math for every one-point increase in their GPA (Acosta et al., 2016, p. 6).

Developmental Mathematics Co-requisite Model

Higher education institutions nationwide have attempted to reduce the requirement for developmental mathematics courses by introducing innovative methodologies and technology (Daugherty et al., 2018; Hilgoe et al., 2016). In one early corequisite model, East Carolina University implemented a required 50-minute weekly session as well as three-hour attendance at a virtual learning facility managed by mathematics instructors and tutors (Hilgoe et al., 2015, p. 376). The passing rate for that academic year (2012-2013) was 72.65% and 70.90% consecutively which would be considered noteworthy (Hilgoe et al., 2015, p. 377).

Cafarella's 2016 article, "The Myths of Redesign in Developmental Mathematics," touches upon the emporium model as well as compression of existing course models, citing Twigg's (2011) work on the emporium model which entails a developmental mathematics class being taught in a computer laboratory setting where students may accelerate in the course schedule and complete the developmental component prior to the semester's end. Among the software utilized by many higher education institutions, including the Texas institution examined by this study, are ALEKS and MyMathLab. Twigg (2011) justification for the expanded use of technology is the contemporary undergraduates' positive response to the interactive model.

Diehl (2017) published her work on Structure Learning Assistance, an element of the corequisite mathematics and supplemental instruction model, to reduce mathematics anxiety among developmental students. Structured Learning Assistance has the potential to address aspects that enables undergraduates to undertake course content/curriculum with support from a Structured Learning Assistance leader. The findings from the Structured Learning Assistance Leaders Program prove that interventions such as this can improve academic performance in mathematics and progression in degree program (Diehl, 2017).

Mireles et al. (2014) wrote about the *Fundamentals of Conceptual Understanding and Success Corequisite Model for College Algebra* was established as part of the Developmental Education Demonstration Projects (DEDP) in Texas, and incorporated multiple academic support services as well as courses employing best practices to expedite student completion of college level mathematics course. This model used repeated measures of students' mathematics ability and of students' course grades as a baseline comparison data to provide evidence of a correlation between the FOCUS Intervention and improved mathematics proficiency, lower withdrawals from courses and better final course grades. The FOCUS Intervention allowed undergraduates who were traditionally barred from enrolling in College Algebra until they successfully completed their developmental mathematics requirement, were allowed to enroll in College Algebra developmental mathematics concurrently with the caveat that they avail themselves of academic support. The results of this study revealed that improvements in mathematics proficiency were statistically significant for undergraduates in the FOCUS Intervention; that they were significantly less likely to drop their course (6.3%) compared to the baseline comparison group (16.4%); and there was a high probability that they would earn higher grades (Mireles et al., 2014, p. 30).

Retention and Graduation of Underprepared Students

Developmental mathematics courses consistently experience larger enrollments than other developmental education courses and up to 80% of these courses utilize part-time instructors rather than tenured faculty (Gerlaugh et al., 2007, p. 3). Shields and O'Dwyer (2017) conducted a study to address the correlation of enrollment in developmental courses and completion of undergraduate studies controlling for demographic characteristics and preparation as well as their undergraduate experiences and higher education institutional characteristics to shed light on implementation of developmental programs to increase graduation rates. The researchers revealed a negative correlation between developmental courses and completion of undergraduate studies. In addition, the researchers discovered that undergraduates who took multiple developmental courses were negatively impacted (Shields & O'Dwyer, 2017). Research conducted by David Fike and Fike (2008) found that undergraduates who fail or withdraw from first developmental mathematics course are more likely to withdraw from higher education.

Acee et al. (2017) enlisted undergraduates to identify those factors that inhibit their academic performance. Results from this study suggest that undergraduates identified various academic and nonacademic obstacles to academic performance as well as successful completion of the course and their program of study. Bradburn and Carroll's (as cited in Acee et al., 2017, p. 3) 2002 study revealed 36% of those undergraduates identified financial reasons as the cause for who their withdrawal from higher education while 18% pointed to personal or family matters, and only 4% named academic difficulties. Acee et al. cited Matross and Huesman's 2002 paper which states that undergraduates who "stopped out," meaning they left with the intention of returning to higher education in the future, tended to cite financial difficulties or employment obligations as the foundation of their decision-making, while those who withdrew with no intention to return identified academic issues as the cause for their decision.

Financial Implications of Developmental Coursework

Hilgoe et al. (2016) addressed the financial implications of taking developmental mathematics courses. Undergraduate students identified as needing developmental courses incur the additional cost of tuition and fees towards courses/credits that are not applicable to their chosen field of study. In addition to the financial burdens, underprepared students may also contend with the apprehension of entering higher education with insufficient mathematics knowledge or skills and, thus delaying their graduation by a semester or academic year (Hilgoe et al.). Barry and Dannenberg (2016, as cited in Valentine et al., 2017) estimated the cost of a developmental course to be approximately $3,000 and add an additional $1,000 to an undergraduate's student loan debt.

Method

A quasi-experimental study was utilized to compare two developmental mathematical models, co- and pre-requisite. Retention and passage of college algebra were dependent variables.

The institution of higher education used for this study reported an enrollment of 9,207 for fall 2016 according to its Fact Book and is an accredited member of the Southern Association of Colleges and Schools (SACS). Participants for this study were selected purposefully as participants of interest to the institution studied. In accordance with the guidelines provided by the Texas Higher Education Coordinating Board (2014), applicants who attain a score of ≥ 350 on the mathematics component of the Texas Success Initiative Assessment are considered “college ready” and, therefore, only students with TSIA scores lower than 350 were included in this study. Data from fall 2015 through spring 2018 semesters were analyzed. Pre-existing archival data of student academic records were obtained from the university’s Office of Institutional Research. Data from the same platform are used to comply with reporting to state and federal agencies, and so were assumed to be accurate.

Academic advisors employ a holistic approach to student course placement. Advisors utilize a students’ TSIA results, their SAT and/or ACT test scores and high school GPA along with the combination of Algebra I and II grades to determine placement in mathematics courses. Incoming students attending the higher education institution that is the setting of this study who attain an SAT score of 480 - 530 and lower were placed in the standalone developmental course, Developmental Algebra (MATH 0302), which did not have a supporting laboratory corequisite. Consequently, students whose SAT scores fall between 530 and 550 are placed in the lower college-level mathematics course (MATH 1314) with a corequisite laboratory (NCBM 0101) for additional support.

The dataset included developmental mathematics model completed (either co- or pre-requisite college algebra), retention (withdrew/failed or passed), and passage. Passage was measured in two ways: 1. passage with an A, B, C, or D as the grade in accordance to the institution’s policy; and 2. passage with an A, B, or C as the final grade in accordance to the State of Texas criteria as successful completion of a developmental course. The number of records was 766.

Grades were assigned by various instructors who taught the courses. Consistency among instructors was strengthened by the use of rubrics to assess student understanding of course curriculum through assignments and testing. Content of courses were aligned with objectives for introductory college level mathematics set by the state of Texas.

Results

Three research questions were addressed. Differences in the proportion of undergraduates who completed college algebra; who passed with an A, B, C, D grade; and, who passed college algebra with an A, B, C grade were compared. Comparisons were made between students who took a prerequisite and co-requisite model developmental mathematics course. Table 1 presents results of the chi square two-way contingency table analyses.

Table 1

Proportions of Undergraduates Who Completed and Passed College Algebra by Developmental Model (N = 766)

Dependent Variables	Developmental Model: Pre-requisite (within group %)	Developmental Model: Co-requisite (within group %)	Overall (within group %)	Chi square two-way contingency table analysis
Completed	239 (54.7%)	328 (99.7%)	567 (74.0%)	Yates χ^2 (1) = 195.4 p = .000 φ = .51
Passed with A, B, C, D	216 (49.4%)	295 (89.7%)	511 (66.7%)	Yates χ2 (1) = 135.03 p = .000 φ = .43
Passed with A, B, C	192 (43.9%)	256 (77.8%)	448 (58.5%)	Yates χ2 (1) = 87.3 p = .000 φ = .34

Statistically significant differences (p = .000) were found between the proportions of undergraduates who completed; passed with an A, B, C, or D; and who passed with an A, B, or C based on whether they took the pre-requisite or co-requisite model for developmental math. Effect sizes indicated medium (φ = .34) to large (φ = .51) magnitudes of difference. The magnitude of difference decreases for the association as completion/passage criteria increase.

Summary, Conclusions, Recommendations and Implications

This quasi-experimental, study examined the effectiveness of two developmental mathematics models, a co-requisite laboratory taken concurrently with the introductory college level mathematics (College Algebra); and a traditional prerequisite model that is taken sequentially prior to the college level mathematics. Though the intent of both developmental models is to help undergraduates successfully complete the mathematics component of their undergraduate degree programs, Ding's (2016) study findings suggest that undergraduate students who are required to register for developmental mathematics courses experience more anxiety towards examinations. Consequences of this associated anxiety may contribute to students' struggles not only often fail the developmental mathematics course, but required multiple attempts of the same developmental mathematic course before successful completion, hence some may even opt to defer taking the required developmental mathematics courses (Ashcraft & Moore, 2009; Boylan, 2011; Hembree, 1990; Maloney & Beilock, 2012). For these reasons, the Texas Higher Education Coordinating Board developed the Non Course-Based Option (NCBO) model, upon which the co-requisite model is based, to provide interventions, the most common being open lab, tutoring and/or supplemental instruction, to aid undergraduate students to progress to credited courses effectively and efficiently to save the student time and money (Texas Higher Education Coordinating Board, 2016). As with this study, Wilder and Berry's (2016) experimental study found retention in the emporium model was significantly higher than the traditional model or instruction. The emporium model incorporates computerized learning resources and active learning strategies to enable undergraduates to master course content and concepts. The co-requisite mathematical model that is employed in this study contains elements recommended by Wilder and Berry. The academic and personal support students can receive in the co-requisite model can result in higher self-concept regarding mathematics. As Kargar et al. (2010) found, a positive attitude towards mathematics results in increased comprehension of the coursework, motivation towards mathematical thinking, as well as commitment to success with additional time and effort being made during the duration of the course semester.

Beyond the psychological stigma, the problem with under-prepared students starting their program of study enrolled in developmental education courses is twofold: financially, students who are placed into developmental courses, risk incurring an added expense given that federal financial aid only pays up to 140 credits per student toward an undergraduate degree. Bradburn and Carroll's 2002 study that revealed 36% of those undergraduates identified financial reasons as the cause for who their withdrawal from higher education and only 4% named academic difficulties (p. 14). Matross and Huesman's 2002 paper states that undergraduates who left with the intention of returning to higher education in the future, tended to cite financial difficulties while those who withdrew with no intention to return identified academic issues as the cause for their decision.

Academically, developmental courses are likely to postpone a student's graduation date. While this study focused on retention through and completion of developmental courses, other studies such as Benken et al. (2015), contended that embarking on developmental mathematics courses can lead to students withdrawing from higher education altogether before completing the sequence of mathematic requirements for their chosen field of study. Researchers have consistently found that placement into a traditional developmental mathematics model of progressive courses can predispose undergraduates to failure (Grubb, 1999; Grubb & Gabriner, 2013; Melguizo et al., 2008).

The findings of the study align with the results found in several studies conducted regrading developmental mathematics courses. This study identified the co-requisite developmental mathematics option as more effective than a traditional model for under-prepared students to successfully progress in their chosen program. Like this study, Jaggars et al. (2015)

studied the course design of developmental education that includes accelerated models and found that those undergraduates who enrolled in the accelerated course sections had a higher probability of completing subsequent credit bearing coursework within three years. However, they stipulated that the course design be rigorous and relevant by combining college-level coursework with personalized support to ensure undergraduates can continue their academic progress. Diehl's (2017) work on the co-requisite mathematics and supplemental instruction model suggest that interventions improve academic performance in mathematics and progression in degree program.

This study revealed from its findings that there was a significant difference in completion and passage between the prerequisite developmental mathematical model and the co-requisite mathematical model. Data suggests that the co-requisite laboratory results in better retention and higher passing rate. In light of these results, the following recommendations are made to further enlighten those who have a vested interest in developmental mathematics models at the higher education level: Studying one Texas HSI limited the sample size and diversity of the undergraduates considered as well as affected the data that was provided and analyzed, therefore, future research may consider expanding the additional higher education institutions that provide both traditional prerequisite and current co-requisite mathematical models to study this vital component of higher education regionally or nationally as well as ensuring diversity in ethnicity, socioeconomic status and gender.

Given that traditional prerequisite developmental mathematics courses are usually lecture-based and often utilize archaic methodologies and assessments such as "skill and drill" with little or no supplemental academic support, and results in undergraduates withdrawing from the course, it may be worth consideration adopting a co-requisite mathematical laboratory that employs methodologies similar to the prerequisite model (Grubb, 1999; Grubb & Gabriner, 2013). This may counter the effects that researchers Fong et al. (2015) studied among students placed into a traditional developmental mathematics model and their predisposition to failure. Once these adaptions have been implemented, educators and administration should consider conducting a similar quantitative study to this one to evaluate the adaption of best practices in a comparison of the prerequisite developmental model, followed by a qualitative study that includes both faculty, students and laboratory staff/facilitators or a mixed methods study to expedite the implementation recommendations of such a study.

The results of this study affirm previous assertions that placement of under-prepared students into a traditional prerequisite developmental mathematics model can predispose them to failure (Grubb, 1999; Grubb & Gabriner, 2013; Melguizo et al., 2008). Also, results confirm that the co-requisite developmental mathematics model may remedy the additional financial burden and delay in completing students' programs of study which puts undergraduates at risk of being unable or unwilling to persevere (Melguizo et al., 2008).

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