Commuting the Math Sentence: Accelerating Developmental Mathematics Using the Co-Requisite Model

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This study compares the results of a developmental co-requisite program with those of a traditional pre-requisite program in an attempt to determine whether the two models provide equivalent levels of effectiveness and efficiency.The research focused on gateway course completion scores and final exam scores for undergraduate students enrolled in a college-level quantitative reasoning course at a public four-year university in the mid-west. The results of this study suggest student success may be improved through the implementation of co-requisite pathways. A learner-centered approach to teaching, one offering just-in-time support, is recommended in this study.The co-requisite model coupled with evidence-based instructional methods demonstrates a promising practice in developmental education worthy of further inquiry.

Recent reform movements questioning the efficiency and outcomes of developmental mathematics education have influenced rapid modifications in course design and student placement (Belfield, Jenkins, & Lahr, 2016). In particular, the effectiveness of methods of assessment for placement have come under intense scrutiny. Questions have arisen as to how well ACT, or any other single standardized test score, reflects student ability and whether current placement policies effectively interpret these scores (Bettinger, Evans, & Pope, 2013). While many institutions use various assessment software programs, some either use proprietary means of placement or tie the placement results to institutional course pathways (Hughes & Scott-Clayton, 2011).

In this paradigm, developmental education courses could have several gradations bearing various levels of college credit. For instance, a student who lacks ACT scores but takes a placement exam at a college testing center, having not received mathematics instruction in recent years, may struggle to adequately demonstrate actual proficiency. This placement score often leads to a prescribed course pathway in developmental courses that may or may not bear credit toward earning a credential (Vandal, 2014). Further, many students do not complete the assigned developmental course sequence (Bailey, Jeong, and Cho, 2010; Parker, Bustillos, & Behringer, 2010; Parsad & Lewis, 2003; Williams, 2016). At best, placement test effectiveness is limited to specific subject areas and, devoid of multiple measures such as high-school grade point average, may fail to add value to developmental course placement (Belfield & Crosta, 2012).

Another concern regarding placement and developmental programs is that students with developmental needs are disproportionately represented by individuals from first-generation and low-income backgrounds (Bettinger, Boatman, & Long, 2013). Many of these students have academic risk factors that developmental courses can both alleviate and exacerbate. For instance, a developmental course may be paced or structured in such a manner that it meets a student's current proficiency level as indicated by the placement exam. Past paradigms dictate that a student is best served by this arrangement and, in this instance, some academic risk factors are alleviated. However, for each developmental course taken, an at-risk student is potentially exposed to a new set of risk factors that include, but are not limited to, additional time to degree during which chaotic external factors threaten student progress, increased likelihood of financial aid friction related to lack of satisfactory academic progress, setbacks in articulation agreements between institutions where credit does not transfer, or simple inability to successfully navigate the next course in the sequence (Super, 2016).

Against this backdrop of national issues, institutions have been under pressure to redesign placement practices as well as developmental coursework. This pressure led the researchers to investigate the co-requisite placement option prior to redesigning the university placement policies. While critics have noted that many initiatives lack rigorous evaluation (Mangan, 2015), the co-requisite pilot described in this study included an evaluation plan from the beginning. This study was conducted at a mid-size, moderately selective, public institution in the mid-west (MWU). Here, various realities encouraged a reassessment of developmental mathematics education. First, cyclical course reports, which showed how students in the developmental mathematics sequence failed to earn college-level mathematics credit, drove regular conversa-

tions about student progress. Secondly, mounting national reforms, including but not limited to Complete College America initiatives, provided a critical lens through which to evaluate student performance locally. Finally, political influence led, in part, by Complete College America's recommendations prompted institutional leaders and faculty to consider pre-emptive initiatives in a deliberately designed pilot process.

Co-requisite Model

Co-requisite courses represent an attempt to alleviate short- and long-term risk factors for students lacking academic preparation and proficiency. While shortening time to credential has inherent economic benefits in reduced cost, co-requisite courses may also help alleviate course misplacements that further contribute to debt burden (Jaggars, Hodara, Cho, & Xu, 2015). One difficulty is identifying whether co-requisites have limited application or whether their use can be scaled across learners of all levels of proficiency. Many states have adopted policies or incentivized institutions that promote the implementation of co-requisite courses (Venezia & Hughes, 2013). While many co-requisite courses have shown promise in a variety of contexts, questions remain as to whether this pathway has helped increase the progression rates, particularly for students demonstrating significant need for developmental support (Kosiewicz, Ngo & Fong, 2016).

Developmental education is structured differently among institutions of higher education. Some developmental programs are located in specific disciplines, others are provided by a student support center, and others are delivered through a unique centralized academic department. Depending on the structure, faculty perceptions can both promote and limit the advancement of co-requisite designs (Walker, 2015). Co-requisite courses require a concurrent learning experience providing just-in-time support to students who, under other circumstances, would not yet be enrolled in gateway courses. Gateway courses are required, college-level content courses that students must successfully negotiate before formally entering a program of study. Hence, these courses are "gateways."

Adopting a co-requisite course presented several challenges for the participating institution. Since co-requisite courses are, essentially, a result of reform, implementation required clear and consistent messaging with various MWU stakeholders. For example, academic advisors were crucial to the process, but some struggled to understand the concept or were reluctant to place developmental students in an accelerated path that was, at the time, untested. Since, at this institution, developmental mathematics and gateway mathematics are housed in distinct departments in separate colleges, creating a cooperative faculty linkage in the co-requisite pairing faced structural challenges.

Study Design

The purpose of this study was two-fold. First, the researchers wanted to determine whether the co-requisite and pre-requisite models provided equivalent levels of effectiveness in supporting student course completion and achievement on the common final exam. Second, the authors wanted to determine whether the co-requisite model could help alleviate risk factors common to students needing developmental education, specifically time devoted to the mathematics sequence and costs associated with the sequence.

The co-requisite model described in this study required interdepartmental collaboration between faculty in separate colleges at MWU. Full-time, tenure-track faculty in the College of Education instructed the developmental mathematics lab (DML), a 2 credit hour course. The developmental mathematics instructors focused on using learner-centered strategies and cooperative learning structures to assist students in developing social, emotional, and intellectual skills. Graduate assistants, instructors and full-time tenure faculty in the College of Health, Science and Technology instructed the gateway mathematics course (MATH 100). The curriculum for MATH 100, a 3 credit hour gateway course, included topics in set theory, geometry, probability and statistics. Each instructor of MATH 100 determined his or her own course evaluation system. Variations between the MATH 100 evaluation systems included the use of extra credit, weighted grading systems, and graded attendance. However, all instructors administered a common final assessment.

The sample for this study included (N=699) undergraduate students enrolled in MATH 100. Archived data from four semesters was collected and analyzed by the Office of Institutional Research. Data included student ACT mathematics sub-scores, final MATH 100 course grades, and scores on the MATH 100 common final examination.

For the purpose of this study, three groups were structured for inquiry. Group One contained 80 student participants enrolled in MATH 100 and the co-requisite DML concurrently. Students in this group were those with ACT mathematics sub-scores below 22 and who would have traditionally been placed into the developmental pre-requisite pathway, based on their ACT mathematics sub-scores. These participants received learner-centered, just-in-time academic support two days a week in the DML course while attending the traditional MATH 100 course three days a week. The treatment spanned one semester for the course and lab totaling 5 credit hours in course load.

Group Two was comprised of 224 students (ACT sub-scores of less than 22) who had previously completed the developmental algebra pre-requisite pathway. The pre-requisite algebra pathway required student enrollment in an emporium model. This model, first introduced at Virginia Tech, requires student interaction with modularized online tutorials (NCAT, 2013). Primarily self-directed, these students completed coursework independently with opportunities to seek assistance from graduate student course facilitators. Students in Group Two participated in the default pre-requisite course sequence that spanned two 16-week semesters in two unassociated 3-credit hour courses, for a total of 6-credit hours.

Finally, Group Three included 395 students who met the gateway enrollment criteria without developmental support. These students achieved an ACT math sub-score of 22 or higher and were identified as academically prepared for the gateway course. Each group completed the common final exam to determine mastery of the student learning outcomes at the end of the semester of enrollment.

Findings

Group One had a mean ACT mathematics score of 17.03 with a standard deviation of 1.62. Of these 80 students, 78.75% completed the gateway course with a 70% C or higher. Group Two had a mean ACT mathematics score of 17.17 with a standard deviation of 1.86. This ACT profile is quite similar to those of Group One. Of these 224 students, 75.00% completed the general education course with a 70% C or higher. One student had an ACT mathematics score above the required score of 22. Reasons for placement in this course are unknown. It is possible that the student elected to take a developmental course as a primer prior to enrolling in the gateway course. Group Three had a mean ACT mathematics score of 22.61 with a standard deviation of 3.71. One student had a score of 11, yet did not enroll in a developmental course at MWU. The reason for this is unknown. Of these 395 students, 90.13% completed the gateway course with a 70% C or higher. Descriptive statistics can be found in Table 1.

Table 1

ACT Mathematics Scores

	N	Mean ACT math sub-score	Standard Deviation	Minimum	Maximum	Completed MATH 100 with 70% or higher
Group 1	80	17.03	1.62	13	21	78.75%
Group 2	224	17.17	1.86	9	27	75.00%
Group 3	395	22.61	3.71	11	34	90.13%

In addition to examining course completion data, a one-way analysis of variance was computed comparing the final exam scores of 479 subjects. This sample did not include participants who withdrew from the course, were exempt from the exam by an instructor, or who completed the final exam at a time other than the scheduled testing date. This comprehensive exam consisted of 28 multiple choice questions. Students were given 120 minutes to complete the exam and were permitted the use of calculators. The grand mean of the post-assessment was 19.35 with a standard deviation of 4.33. A significant difference was found ($F(2, 477) = 71.41$, $p < .0001$) among the groups. A Duncan multiple range test ($p = .05$) was used to determine the nature of the differences between groups. This analysis revealed that students in Group Three scored significantly higher ($m = 21.34$, $sd = 4.02$) than students in Group One ($m = 17.07$, $sd = 4.54$) and students in Group Two ($m = 16.37$, $sd = 4.81$). Group One and Group Two were not significantly different from each other. See Table 2 for descriptive statistics and Table 3 for the ANOVA.

Table 2

Common Final Exam Descriptive Statistics

	N	Mean	Standard Deviation	Minimum	Maximum
Group 1	55	17.07	4.54	7	25
Group 2	145	16.37	4.81	3	27
Group 3	280	21.34	4.02	5	28

Table 3

Common Final Exam ANOVA

ANOVA					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2682.81	1341.41	71.41	< .0001
Error	477	8960.68	18.79		
Total	479	11643.49			

Conclusion

This co-requisite model shows promise in three outcomes. First, students who were unable to demonstrate acceptable mathematics proficiency based on the ACT were able to demonstrate college-level mathematics mastery with this model of just-in-time, learner-centered support. Second, students receiving co-requisite treatment were able to move through the developmental and gateway sequence more efficiently. This pace could help support a more timely progress towards degree attainment, which helps mitigate certain risk factors associated with delayed progress, such as stopping or dropping out (Vandal, 2014). Students with extended pathways and interrupted enrollment are often less likely to complete an undergraduate degree than students with shorter pathways and continuous

enrollment (McCormick & Carol, 1999; Smart & Paulsen, 2012). Finally, students were able to receive the treatment at a reduced credit load, which corresponds to decreased cost burden, which is another factor impacting retention and persistence among at-risk populations.

Here, the co-requisite model has expanded the understanding of being learner-centered to include academic risk factors that may not be directly linked to mathematics proficiency: namely, the daily access to mathematics faculty, coupled with the accelerated course sequencing, allows fewer opportunities for unexpected challenges that tend to affect students in need of social, emotional, and intellectual support. While access and support were available in the emporium model pre-requisite sequence, study participants appeared to benefit from the required daily interactions with instructors, classmates and content offered by the co-requisite model. This particular just-in-time model allowed students to focus on college-level mathematics without first spending a semester revisiting content previously covered in secondary mathematics courses.

A few limitations in this study should be noted. The sample is limited to a single institution and may not be representative of all students with developmental mathematics needs. The researchers were not able to control for demographics or particular sub-populations beyond at-risk students who performed below ACT expectations for college readiness. The researchers were not able to account for instructor preparation, credentials, paradigms regarding pedagogy, or classroom teaching experience.

The use of co-requisite instruction bears promise and requires further inquiry. Recommended areas for further research include the impact of co-requisite courses on achievement and the application of co-requisite courses beyond developmental education. While many states are attempting to scale this or similar accelerated learning models, developmental educators have the opportunity to investigate and promote best practices in co-requisite education to ensure its outcomes continue to create equitable opportunities for all students.

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