Equity in Developmental Mathematics Students' Achievement at a Large Midwestern University

Kenneth Bradfield
Michigan State University

With so many students entering college underprepared for the mainstream sequence of mathematics courses, mathematics departments continue to offer developmental or remedial courses with innovative methods of delivery. In order to support students in their college education, researchers continue to investigate the effectiveness of undergraduate remediation programs with mixed results. This paper provides quantitative data from an NSF-funded project from a large Midwestern university over three years of a developmental mathematics course. Pre- and post-measures show that both urban and African-American students benefited the most from supplemental instruction in contrast to the online-only format. Based on these results, I offer recommendations for undergraduate mathematics departments to support equitable opportunities for marginalized students ensuring a successful developmental mathematics program.

Keywords: Developmental mathematics; Equity and diversity

Mathematics departments across the country offer developmental courses or remediation to support the entering students they deem unprepared to meet the entry standards of their introductory courses. Researchers estimate more than a third of all incoming freshman sign up for a developmental course upon entering college often resulting in an over-abundance of students enrolling in developmental courses (Bettinger et al., 2013; Scott-Clayton, Crosta, & Belfield, 2014). With the cost of these programs nationwide for institutions of higher learning in the billions of dollars (Bettinger, Boatman, & Long, 2013), mathematics departments search for innovative solutions to ensure they can afford to support the education of as many students as possible.

The variety of delivery methods that mathematics departments use to provide content and instruction often lack in research-based teaching methods or resources creating an inequitable environment in terms of educational opportunity in developmental programs. TAs or faculty with little to no training in teaching strategies typically instruct these courses coupled with the over-representation of minorities in developmental courses can potentially cause students more harm in the first years of college (Attewell et al., 2006; Larnell, 2013). Designed as gateways to future mathematical success for all students, Bonham and Boylan (2011) acknowledged that "developmental mathematics as a barrier to educational opportunity represents a serious concern for the students as well as higher education policy makers" (p.2).

Considering these concerns, our NSF project[1] team reviewed three years of quantitative data collected from the developmental mathematics program at a large Midwestern university to compare the effects of various instructional methods between groups of students with similar backgrounds. Results in this paper compare how urban, low-income, and African-American students (who made up approximately one-eighth of the entire population of students enrolled in the online math course over the three year period) faired in an online-based tutoring program

[1] This project was supported, in part, by the National Science Foundation awarded to Kristen Bieda (PI), Beth Herbel-Eisenmann, Raven McCrory, and Pavel Sikorskii (Co-PIs) under the grant DUE-1245402.

with or without additional face-to-face instruction faired compared to each other. The success of the urban and African-American students with additional face-to-face instruction compared to their peers provides a window into how researchers can evaluate and mathematics departments make changes to their developmental program to ensure more equitable opportunities for all students. I will first provide some background literature to further situate this study.

Literature Review

Current issues surrounding developmental mathematics consist of how mathematics departments select students and deliver content to ensure students' successful completion of their degree requirements and how researchers evaluate the effectiveness of programs providing reliability and generalizeability. Scott-Clayton, Crosta, and Belfield (2014) found that placement methods, typically involving the use of an exam, fail to correctly identify the students who need remediation. Other community college programs have experimented with incorporating high school transcript data (Jackson & Kurlaender, 2013); however, Bettinger et al. (2013) acknowledged that tests and high school performance still ignore the unseen qualities of students that influence their success in their first year of college, e.g. study habits and perseverance. Researchers continue to search for the right combination of indicators for placement and eventual success in developmental mathematics course (Scott-Clayton et al., 2014).

Mathematics departments are often limited by their resources and materials to offer their students research-based mathematics resources and instruction. Bonham and Boylan (2011) argued that successful programs incorporate technology and innovative materials for the classroom, extracurricular resources for students, and professional development for instructors. Since not all institutions can provide these opportunities for their students, innovative solutions arise that include online resources or tutoring programs paid by student tuition money. Researchers continue to search for opportunities for mathematics departments to provide resources and instruction to support the students who need them most.

In addition to the selection of students and the delivery methods, scholars have discussed methods to evaluate developmental mathematics programs to ensure reliability and provide higher education policy makers justification to enact institutional changes. Bettinger et al. (2013) noted that the amount of variation due to geography, student backgrounds, and other factors that currently go unseen that cannot be measured quantitatively or provided on a high school transcript and called on more studies to explore this variability. In providing data from particular geographic areas and groups of students, researchers can begin to explore similarities and differences to facilitate discussion around a complex solution to the complex problem of inequitable opportunities in developmental mathematics education.

Considering these discussions, the NSF-funded project investigated quantitative data from a census of all students in three years of the developmental mathematics course at a large Midwestern university to answer the following question:

- What effects does a supplementary face-to-face instruction in a developmental mathematics course have on different subpopulations of students' performance and future participation in mathematics?

Methods

I present quantitative data over three years of an NSF-funded project comparing the various methods of delivery of a developmental mathematics course at a large Midwestern university. Approximately 800 students each year enrolled in the online version of the developmental mathematics course, as determined predominately by placement exam score. The program ALEKS is the curriculum for the online course. Freshman identified by advisors as at-risk for failing first-year courses enroll in groups of around 15-20 students in a supplementary face-to-face section that meets twice a week with each class lasting two hours. Each class is taught by mathematics graduate students with the exception of one section taught by senior pre-service mathematics teachers as part of an NSF-funded project in concert with the teacher education department. While the sections led by mathematics graduate instructors engaged in material directly supporting the students' work on the ALEKS program, the seminal section with pre-service mathematics teachers engaged in a curriculum and instructional methods grounded in mathematics education research.

The project investigated the effect of taking any of the supplementary face-to-face sections on students' success in the online developmental course and on their performance in subsequent math courses. In this paper, I present comparisons of the percent difference between the means of quantitative pre-measures (ACT mathematics score, university placement exam, ALEKS pre-score) and post-measures (ALEKS post-score, final exam, final grade) to determine differences in outcomes between African-American, urban, and low-income[2] students who enrolled in the online-only version of the course and those who enrolled in the supplementary face-to-face sections. These particular students were selected based on the large percentage of students self-reported as African American and low-income hailing from the large urban area nearest to the university (75% and 90% respectively) and the teacher education department's interest in potential future summer enrichment programs for students from this area. I also provide similar comparisons between the enrollment and grades in the pursuant credit-bearing mathematics course for the students in the first year of the data set.

Results

The data for each of the three years demonstrates that African-American, urban, and low-income students who took the supplementary face-to-face course made significant gains in the online course compared to their peers who were not enrolled in the face-to-face enrichment course.

Table 1 includes the percent difference between the face-to-face and online only students within the subpopulations of students from the large urban area, low income, and African-American separately. Overall the data demonstrates that the face-to-face students started slightly behind and finished significantly ahead in both the urban and African-American groups and started significantly behind and finished slightly ahead in the low-income group. Considering this data also represents census data for a university over three years, this data shows the supplementary face-to-face instruction associates with a significant gain in post-measures across each of these subpopulations.

---

[2] Ethnicity was self-reported while the urban and low-income information was provided by researchers' map of the state near the urban area in question in conjunction with income information by zip code provided by the University of Michigan's Institute for Social Research: http://home.isr.umich.edu/.

Table 1 Percentage Difference between Face-to-Face and Online Group

Urban		Pre-measures			Post-measures		
	ACT Math	Placement	ALEKS Pre	ALEKS Post	Final Exam	Grade
2012	-2.6%	-6.4%	2.5%	***13.7%****	***26.9%****	***21.5%****
2013	***-6.8****	-6.3%	-11.3%	-2.2%	***16.7%****	***10.6%****
2014	-3.7%	-2.0%	-17.4%	2.6%	9.3%	***9.7%****
Low income		Pre-measures			Post-measures		
	ACT Math	Placement	ALEKS Pre	ALEKS Post	Final Exam	Grade
2012	***-5.6%****	***-10.0%****	3.3%	5.5%	8.1%	7.6%
2013	***-6.2%****	-4.3%	-6.3%	0.4%	***21.2%****	***12.5%****
2014	***-4.5%****	1.0%	***-17.0%****	2.2%	2.4%	6.5%
African-American		Pre-measures			Post-measures		
	ACT Math	Placement	ALEKS Pre	ALEKS Post	Final Exam	Grade
2012	0.7%	0.5%	-2.2%	***11.1%****	***15.8%****	***12.5%****
2013	***-5.5%****	***-12.9%****	-14.3%	-2.4%	***15.3%****	***9.1%****
2014	-1.7%	-0.5%	-5.4%	7.0%	***17.9%****	***14.9%****

*Note: * $p < 0.05$, ** $p < 0.01$*

Table 2 Percent Enrolling and Passing Next Math Course in 2012

		N	N enroll	% Enroll	N pass	% Pass
Urban	Face to face	47	35	***74.5%****	18	***38.3%****
	Online	55	26	47.2%	14	25.5%
Low income	Face to face	75	52	***69.3%****	26	34.7%
	Online	122	69	56.6%	41	33.6%
African American	Face to face	84	64	***76.2%****	31	***36.9%****
	Online	113	63	55.8%	29	25.7%
All students	Face to face	171	130	***76.0%****	68	39.8%
	Online	619	394	63.7%	221	35.7%

*Note: * $p < 0.05$, ** $p < 0.01$*

Table 2 shows the percent of students who enrolled and passed the proceeding mathematics course offered by the mathematics department within each of the subpopulations. Overall the data demonstrates that a significantly higher percentage of students enrolled in the next math course across not only all subpopulations but also the entire population of students. In addition, significantly higher percentage of students in the urban and African American subpopulations passed the course (receiving GPA>2.0).

A common theme of both of these tables indicates that the supplementary face-to-face section benefits not only students' performance in the online course for these subpopulations, but also potentially contributes to success in the next math course.

Discussion and Future Directions

These results provide an example of Bettinger et al.'s (2013) call for researchers to compare groups of students with similar backgrounds demonstrating how characteristics through information provided by the registrar can provide an avenue for a positive change in providing students opportunities in developmental programs. Factors to consider for determining students placement that include test scores and high school transcript information (Jackson & Kurlaender, 2013) can potentially include demographic information as well.

Providing students with face-to-face instruction increased the performance of the urban and African-American subgroups in this student population. Universities that offer online-based opportunities could experience strong gains in performance by providing supplementary face-to-face instruction sections to underprivileged students. This is not to say that engaging students in these opportunities is a panacea as students come from diverse backgrounds with a variety of different ways of learning and knowing. Even with the variety of student backgrounds, the data demonstrates sub-populations of student based on demographics that benefited the most from the resources offered by their institution. Although providing students with these sections could improve gains in performance, other mathematics departments should tread carefully and provide instruction that improves students' mathematical proficiency and not knowledge of correct procedures alone (Larnell, 2013; Kilpatrick, Swafford, & Findell, 2001).

As "success" in a mathematics course goes beyond just performance on course exam, future studies could dig deeper into how the students experienced the developmental mathematics program as well as track students' success longitudinally. Although the selection of students attending this institution was not a random sample of the nation, the scale of this case provides a window into a single university over three years to anticipate similar results for other large, public universities. Other mathematics departments could then take their own nuanced steps based on their results to ensure more equitable opportunities for their students' education and ameliorate the inequities in the first year of undergraduate mathematics. Further questions continue to remain to continue the goal of spurring the growth of developmental mathematics programs across the country to meet the needs of all students entering their respective universities:

- What makes face-to-face supplemental courses more successful for students than online-only courses?
- Which universities have similar demographics as the one referenced in this report?
- How can we motivate mathematics departments to make changes supported by evidence to invest in students' developmental mathematics programs?

References

Attewell, P., Lavin, D., Domina, T., & Levey, T. (2006). New evidence on college remediation. *Journal of Higher Education*, 886-924.

Bailey, T., Jaggars, S. S., & Scott-Clayton, J. (2013). *Characterizing the effectiveness of*

developmental education: A response to recent criticism. New York, NY: Columbia University, Teachers College, Community College Research Center.

Bettinger, E. P., Boatman, A., & Long, B. T. (2013). Student supports: Developmental education and other academic programs. *The Future of Children*, *23*(1), 93-115.

Bonham, B. S., & Boylan, H. R. (2011). Developmental Mathematics: Challenges, Promising Practices, and Recent Initiatives. *Journal of Developmental Education*, *34*(3), 2-10.

Jackson, J., & Kurlaender, M. (2013). College readiness and college completion at broad access four-year institutions. *American Behavioral Scientist*, *58*(8), 947-971.

Kilpatrick, J., Swafford, J., Findell, B., & National Research Council. Mathematics Learning Study Committee. (2001). Adding it up: Helping children learn mathematics. Washington, DC: National Academy Press

Larnell, G. V. (2013). *Toward reforming non-credit-bearing remedial math courses*. Chicago, IL: UIC Research on Urban Education Policy Initiative, University of Illinois at Chicago . Retrieved from http://www.scribd.com/doc/149829260/TowardReforming-Non-Credit-Bearing-Remedial-Math-CoursesScott-

Scott-Clayton, J., Crosta, P. M., & Belfield, C. R. (2014). Improving the targeting of treatment evidence from college remediation. *Educational Evaluation and Policy Analysis*, *36*(3), 371-393.