Boosting Tutoring or Homework in Introduction to Algebra Classes Leslie B. Goldstein, Brian L. Burke, and Sandra Gilpin, Fort Lewis College

Abstract

The current study investigated whether requiring students to visit the campus tutoring center or to complete online homework via MyMathLab boosted their performance in Introduction to Algebra developmental mathematics classes. The same instructor taught three different sections of the course in Fall 2013. Student persistence and final course grades were higher in both treatment group sections (tutoring and MyMathLab) compared to the control. However, only students in the MyMathLab group performed statistically significantly better in their next math class (Intermediate Algebra) the following semester, nearly a full letter grade higher than students from the control and tutoring groups. Implications for practice are discussed.

Keywords: developmental mathematics, introduction to algebra, online homework, tutoring center, self-efficacy

Boosting Tutoring or Homework in Introduction to Algebra Classes

Developmental mathematics courses are becoming increasingly necessary for four-year colleges. Only 42% of high school graduates in 2015 met the benchmark for being "college ready" in mathematics, down from 45% in 2011 ("The Condition of College & Career Readiness," 2015). Accordingly, the National Educational Longitudinal Study found that 28% of traditional undergraduates take at least one developmental mathematics course (Attewell, Lavin, Domina, & Levey, 2006). Of the 23,490 high school graduates who matriculated to college in Colorado in 2014, 6,926 students (30%) were not college ready and required at least one developmental course, with the most common subject area being mathematics (Colorado Department of Higher Education, 2015). Not only are an increasing number of students being placed into developmental mathematics courses, but students fail these courses at alarming rates (Cullinane & Treisman, 2010): Only 60% of Colorado students pass their remedial math classes (Colorado Department of Higher Education, 2015). As such, developmental mathematics has become "a burial ground for the aspirations of myriad college students trying to improve their lives through education" (Cullinane & Treisman, 2010, p. 2). On a positive note, though, other researchers have found that students who enroll in developmental mathematics may be more likely to complete a Bachelor's degree than students not enrolled in those courses (Bettinger & Long, 2005; Noble & Sawyer, 2013), which suggests that developmental education has an important role to play in college success.

Background

In 2008, the public four-year liberal arts college in this study received a Title III Strengthening Institutions Grant from the U.S. Department of Education for the purpose of improving mathematics courses and instruction, especially among underserved populations such as Native American students. This grant has supported two complementary research studies described herein. The college has a separate department to teach developmental mathematics courses termed the Freshman Mathematics Program (FMP). FMP faculty members have a background in mathematics education rather than higher-level mathematics, having been trained as educators rather than doctoral-level researchers. The FMP is responsible for designing and teaching two college-level courses and two developmental courses—Introduction to Algebra and Intermediate Algebra—that are not offered for college credit but rather as a benefit to students to ameliorate their algorithmic skills (Duranczyk & Higbee, 2006). The Title III grant funded research focused primarily on these two developmental courses.

At the study institution, students with ACT Mathematics scores of 17-18 are placed into Intermediate Algebra, whereas students with scores below 17 must first take Introduction to Algebra. In 2011, the first of two studies under the Title III grant tested a redesigned Intermediate Algebra course and found that student performance and satisfaction with the course did not differ from the traditional course; however, success in College Algebra—the next course in the sequence—was statistically significantly higher the following semester among students from the redesigned course sections, especially for Native Americans (Goldstein, Burke, Getz, & Kennedy, 2011).

One persistent issue, however, remains the typically low first-time success rate in the Introduction to Algebra course, the prerequisite to Intermediate Algebra for many students. According to prior data, students fail for two main reasons: They do not attend enough classes or they do not complete enough of their outside-of-class work and assignments. The FMP has instituted a mandatory attendance policy (where 7 absences results in an F grade for the course) for the past decade to address the first reason for the high failure rates. The current study aims to address what may be the second key obstacle to student success: students repeatedly not doing enough work outside of class (on homework, assignments, and/or studying) to effectively hone their mathematical skills. Across colleges, there is evidence of a pronounced decline in the number of hours that full-time college students study, from about 24 hours per week in 1961 to 14 hours per week in 2003 (Babcock & Marks, 2011). The 2012 National Survey of Student Engagement, which included data from over 300,000 undergraduate students from 577 institutions, indicated that only 55% of students at our college report spending 10 or more hours weekly on academic work outside of class compared to 67% at peer institutions and 63% at colleges overall.

To address this second obstacle (out-of-class work), the research literature suggests that four critical variables need to be considered for developmental mathematics students: selfefficacy, self-regulation, motivation, and study skills (House, 2009; Healey, 2013; Otts, 2011). Self-efficacy refers to student confidence in their own mathematical abilities, which has been shown to be a crucial factor in raising mathematics performance, especially for Native American students (House, 2009). Self-regulation (Otts, 2011) encompasses both motivation and study strategies (Healey, 2013) along with the ability to reflect upon one's mathematical learning and how to optimize it. Previous data suggest that developmental mathematics students' self-efficacy and self-regulation at our college manifest in two course-related behaviors that lead to success: using the free mathematics tutoring center and completing their online homework fully, with frequent completion of extra modules (Goldstein et al., 2011).

In this study, we tested the comparative efficacy of these two methods to increase student work outside of class: (a) requiring students to utilize the mathematics tutoring center on campus, a form of indirect instruction led by peers and instructors that has been shown in previous studies to play a vital role in student success in developmental mathematics courses (e.g., Fowler & Boylan, 2010; Fullmer, 2012); and (b) assigning more online homework via MyMathLab (MML), a series of online mathematics modules that engage students in active learning. In a university-based trial, pass rates went from 49% to 72% in three different college-level mathematics classes after adding MyMathLab (Speckler, 2012). There is evidence that online homework may be more effective than traditional textbook-based homework (Dillard-Eggers, Wooten, Childs, & Coker, 2008), particularly for underprepared college mathematics students (Brewer & Becker, 2010).

We hypothesized that both of these interventions—increasing tutoring center use and online math homework completion—would improve student performance and success in Introduction to Algebra. However, previous research has suggested that tutoring centers had beneficial effects for developmental math students in the short- but not in the long-term (Ugo, 2010; Visher, Butcher, Cerna, & Society for Research on Educational Effectiveness, 2011). In accordance, we predicted that only the online homework condition would have a "sleeper effect" of boosting student performance in their subsequent math class the following semester, because students in that condition would be truly practicing the requisite mathematical skills rather than watching others (in the tutoring center) demonstrating or talking them through those skills.

Method

Participants

This study was conducted at a four-year public liberal arts college with a student enrollment of approximately 4,000 students, about 25% of whom are Native American. Despite increased admission standards at the college since 2008, 27% of the freshman class place below college level in mathematics, with 37% of those students being Native American. Demographics of the different course sections under study were as follows: 60-68% female, 34-57% White, 23-48% Native American, and 10-27% Hispanic or Other, with student mean Math ACT scores of 15-16. There were no statistically significant differences between course sections in any of these variables, with χ^2 [2, N = 97] = 0.535, p = .77 for gender and χ^2 [4, N = 97] = 6.83, p = .15 for ethnicity; for ACT scores, ANOVA yielded F(2, 95) = 0.46, p = .63.

Developmental Math Curriculum. Introduction to Algebra provides students with basic algebraic skills, thinking, and study habits. In this course, students learn operations with integers, rational numbers, percentages, simplifying polynomials and are introduced to functions. The next course in the developmental sequence is Intermediate Algebra, which furthers students' comfort with basic algebraic skills and thinking. Students learn simple functions, unit analysis, exponents, and other foundational math skills such as percentages and fractions via a problem-based approach.

Algebra Alcove. Staffed by freshman math program (FMP) instructors and trained peer educators, the Algebra Alcove is a free tutoring center that helps students in their developmental math classes by developing their confidence and skill sets. Students enrolled in any freshman math class may work with tutors just by showing up during posted hours. All peer tutors in the Algebra Alcove attend 5-10 hours of training and do at least 25 hours of tutoring to attain various levels of College Reading & Learning Association (CRLA) certification. CRLA tutor training is held each semester and includes instruction on communication and relationships, rights and responsibilities, student populations, strategic learning, and motivational interviewing (see http://www.crla.net for more details). **Online Homework.** MyMathLab is an online homework program that incorporates two types of adaptive learning—Companion Study Plan Assignments and Personalized Homework— so that instructors have the flexibility to incorporate the style and approach of adaptive learning that best suits the course structure and students' needs. MyMathLab's adaptive study plan acts as a personal tutor, updating in real time based on student performance to provide personalized recommendations on what students should work on next (see http://www.pearsonmylabandmastering.com for more details).

Design and Procedure

The key question of this research was whether students in the first developmental mathematics course should spend more time working in an environment wherein tutors/instructors could answer their questions or more time working online on algorithmic problems on their own with immediate feedback provided. In Fall 2013, the same instructor (LBG) taught three different sections of Introduction to Algebra.

One section was used as the control group and no instructional changes were made. Another section was required to visit the free on-campus math drop-in tutoring center (Algebra Alcove) for 2 hours every week. We chose 2 hours per week as the target because this was more than double the number of hours that students in previous semesters of Introduction to Algebra spent in the tutoring center each week (Kathy Wellborn, personal communication, June 26, 2013). Data were collected monthly from electronic (Accutrack) records to assure students had been visiting the center regularly. The third section was assigned roughly double the amount of online homework (2 hours instead of 1 hour weekly) via MyMathLab modules compared with the other two sections.

Data Analysis

First, we performed a manipulation check using planned comparisons to determine whether tutoring center and online homework hours did indeed differ by class sections as designed. We then examined three different indicators of student performance to assess the full impact of the different versions of these Introduction to Algebra sections: (a) the extent to which students persisted in the course by comparing retention percentage and dropouts (i.e., noncompleters) by section; (b) student performance in the course by comparing specific and total grade components by section as well as by examining correlations of actual online homework and tutoring usage with final course grades; and (c) long-term effects of the intervention by comparing student performance in their next semester's Intermediate Algebra course by prerequisite section (control, tutoring center, or MyMathLab section of Introduction to Algebra). Chi square was used to analyze (a) above and ANOVA was used for all other analyses between the three course sections including manipulation checks, with planned comparisons (Nicol & Pexman, 2010) performed between the two treatment groups and the control group for (b) above and between the online homework group and the two other groups for (c) above in accordance with study hypotheses. Levene's (1960) tests for equality of variance indicated that the assumption was met in each case (ps > .50).

Results

Manipulation Check

Algebra Alcove tutoring center use varied by section as predicted, with the tutoring group (i.e., students for whom use of the center was an explicit component of their course grade) spending a mean of 18.27 hours (SD = 13.57) there during the 14-week semester compared to only 5.07 hours (SD = 8.34) for the online homework group and 8.70 hours (SD = 17.36) for the control group. Results of our planned comparison revealed that there was a statistically

significant difference between the tutoring group and the other two groups, t(94) = 3.92, d = 0.85, p < .001. Interestingly, although students in the online homework group completed roughly double the number of homework problems in MyMathLab each week (and received similar homework grades) compared to the other two groups, the time spent doing the online homework did not vary in a statistically significant way by section. The online homework group spent a mean total of 12.68 hours (SD = 5.37) on MyMathLab problems during the 14-week semester compared to 11.21 hours (SD = 7.00) for the tutoring center group and 10.65 hours (SD = 6.21) for the control group. But results of our planned comparison did not yield a significant difference between the online homework section and the other two course sections, t(94) = .81, d = 0.16, p = .47. Average time spent on each of the twenty homework assignments was about 20 minutes for the online homework group compared to 17 or 18 for the other two groups [t(94) = 1.34, d = 0.28, p = .18 on planned comparison].

Student Persistence

The percentage of students who walked away from the class and did not sit for the final exam was statistically significantly lower for both treatment groups compared to the control group (χ^2 [1, *N* = 97] = 5.09, d = 0.47, *p* = .03). The control group had a 31% walk-away rate (10/32) compared with 10% (3/30) for the tutoring center group and 14% (5/35) for the MyMathLab group.

[INSERT Table 1 ABOUT HERE]

Student Performance

As displayed in Table 1, both treatment groups had higher final grades compared with the control group (d = 0.36), although this difference failed to meet statistical significance (t(94) = 1.69, p = .09). The only grade component difference that reached statistical significance was for

the portfolio grades (student notebooks), which were higher in the treatment groups compared with the control group via planned comparison (t(94) = 2.09, d = 0.46, p = .04).

However, students' level of completion of MyMathLab online homework across sections was significantly correlated with their final course grade, r(97) = .92, p < .001. Students' use of the Algebra Alcove tutoring center across sections was also significantly—though less strongly—correlated with their final course grade, r(97) = .32, p = .002.

[INSERT Table 2 ABOUT HERE]

Subsequent Student Performance

In addition to boosting student persistence and performance in Introduction to Algebra, the MyMathLab online homework intervention also had "sleeper effects" the following semester in the students' next level math class (Intermediate Algebra) according to our second hypothesis. Students in the MyMathLab group performed statistically significantly better in their next math class, with t(35) = 2.11, d = 0.72, p = .04 on planned comparison, nearly a full letter grade higher than students from the control and tutoring groups. Further, the students' level of completion of the online homework in their first algebra class—regardless of which group they were in—was significantly correlated with their final grade in their next algebra class, r(41)= .56, p < .001.

[INSERT Figure 1 ABOUT HERE]

Figure 1 displays the three main outcome measures by group in one graph, with (a) student dropouts in Introduction to Algebra, (b) final grades in Introduction to Algebra, and (c) final grades in Intermediate Algebra the following semester.

Discussion

As more colleges move toward designing and implementing Supplemental Instruction (Feinn, 2004; Peacock, 2008), which involves offering support classes to developmental mathematics students, it will be valuable to determine whether and to what extent the specific interventions tested in this study—mandatory tutoring and/or MyMathLab online homework modules—should comprise parts of that plan.

Based on the study results, students who are required to spend more hours outside of class time—either in the tutoring center or doing online homework—may perform better in their classes than students who are left to their own devices. In general, these students persist longer, get help sooner, and do not fall behind at the same rate. But remediation in mathematical skills may be about more than just getting help through the initial developmental course; the specific *type* of help that students receive may make a substantial difference in the longer run.

Requiring students instead to do more skill practice on their own, as in the online homework section, yielded a sleeper effect (d = 0.72) that may work on multiple levels: Not only do students get practice with foundational skills, but they also receive immediate feedback on their mastery of those skills that may boost their self-efficacy. This finding supports the research that optimal learning occurs only when students rehearse what they have learned on their own (e.g., via MyMathLab) rather than merely getting extra help with the content from a trained guide (e.g., via the tutoring center; Benassi, 2012). Interestingly, this extra online homework (about twice the number of assigned problems) did not actually take the students much extra time—only an additional hour or two across the semester. Whereas the reason for this is unknown, we can speculate that students may have begun to get into a rhythm whereby each subsequent problem of the same type took them less and less time than the initial problems did.

Limitations

There are several limitations to this study. First, although the same instructor taught all three sections of Introduction to Algebra, students were then free to take any of three different instructors for their Intermediate Algebra class the following semester, making the sleeper effect finding a quasi-experimental one. In addition, the initial assignment to course sections for Introduction to Algebra was not random; rather, students self-selected into sections based on their own schedules and preferences. Further, the sleeper analysis did not include over half of the students who chose—for a variety of reasons—not to take Intermediate Algebra the following semester after Introduction to Algebra, despite recommendations that they do so. Moreover, we did monitor students' completion of their 2 additional hours (Alcove or online homework), but those students who did not fully comply were still included in the analyses as we wanted to maintain the external validity of findings. Finally, the online computer program itself may limit generalizability of this study. We chose MyMathLab (MML) because of its feedback components, which are lacking in some free programs. There are other online programs that also provide practice with real-time feedback, but we did not test those here.

Implications for Future Research and Practice

Future studies should examine and compare different online homework tools to see whether they alter student performance and/or sleeper effects reported herein. More online feedback provided may improve students' grades in future classes as their self-efficacy could be further enhanced as a result, especially since the extra homework items did not appear to take much more time. Further, because assigning students additional online homework with immediate feedback was shown to be beneficial here, traditional pencil-and-paper homework with feedback should also be studied for its potential to boost student math grades. Moreover, we do not yet know whether it is the self-efficacy piece that allows these students to perform at higher levels in their future math classes. The students taught themselves some of the content the first time (rather than relying on a tutor) and thus they may have a strong belief that they can teach themselves more content in their subsequent developmental math class. However, the self-efficacy component of independent work has not been thoroughly analyzed; it is thus left to future studies to assess math self-efficacy to determine whether this component rather than something else (e.g., skill rehearsal) was what mediated the sleeper effect.

Another vital implication of this research concerns tutor training. Previous research on the effectiveness of tutoring in elementary and secondary schools has yielded higher effect sizes (d's in the 0.60 range; Bowman-Perrott et al., 2013) than the one found herein (d = 0.36). However, despite the extensive use of tutoring as a mode of instruction and as a learning strategy in higher education, few comprehensive studies have assessed the benefits derived from tutoring in this setting (Rheinheimer, Grace-Odeleye, François, & Kusorgbor, 2010). Even fewer have explicitly evaluated the effects of tutor training on tutees, such as by comparing students helped by trained tutors or faculty versus those assisted instead by a control group of tutors who were not trained (e.g., Staub & Hunt, 1993). One of the shortcomings of most student-run (though faculty-assisted) tutoring centers is that developmental math students are often observers, sitting passively watching the student tutors work the various math problems for them. Even when the tutors engage their students in Socratic learning, the tutee still has the benefit of a guide talking through them each math problem. All peer tutors in the Algebra Alcove, the tutoring center in this research, attend 5-10 hours of training and do at least 25 hours of tutoring to attain various levels of College Reading & Learning Association (CRLA) certification as described above. Whether they also learn how to tutor so that their tutees are not simply passive observers but actively involved in guided self-discovery is an empirical question that merits further evaluation.

Finally, future research should investigate whether there may be a synergistic effect to a combination of tutoring and MyMathLab. Presumably, one of the main purposes of tutoring— ostensibly a form of guided homework completion—is to set the stage and prepare the student to then undertake homework on their own without any prodding or assistance by tutors. Studies could include a condition in which both tutoring center usage and online homework are augmented compared to either one alone or a usual control group.

Conclusion

Our bottom line research question was this: Does it help to "make" students (via your grading scheme) spend more time on mathematics outside of class, either in the tutoring center or doing MyMathLab online homework modules? This study suggests that the answer is "yes" and that the amount of extra time required may not be extensive. Students in both intervention groups persisted in the class at a higher rate than students in the control group. Having time explicitly "mandated" (i.e., as part of their grade) outside of usual class time may have enabled the students to be more successful in their developmental math class. Second, the type of work had a sleeper effect wherein students who did MyMathLab computer-based skill rehearsal with feedback performed better in their next-level math class than students who received individual help from faculty or peer tutors in the campus tutoring center. If these findings can be replicated in various institutional settings, then developmental math instructors should consider making the completion of online skill-building homework a mandatory portion of the course grade, as the intervention of requiring homework with feedback may bolster student success in developmental mathematics and other gatekeeper math courses.

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Table 1.

Percentage Grades by Class Section for Different Course Components of Introduction to

Algebra (Fall 2013)

Grade Component	Class Section	<u>N</u>	Mean Grade	Standard Deviation
Homework	Control	32	70.46	20.82
	Tutoring Center	35	76.65	14.41
	MyMathLab	30	75.93	13.20
	TOTAL	97	74.39	16.55
Portfolio	Control	32	56.73	35.95
	Tutoring Center	35	72.89	28.31
	MyMathLab	30	68.37	27.56
	TOTAL	97	66.16	31.28
Exams	Control	32	59.76	24.06
	Tutoring Center	35	64.54	21.05
	MyMathLab	30	69.53	17.02
	TOTAL	97	64.51	21.14
Final Course Grade	Control	32	64.59	22.58
	Tutoring Center	35	70.82	18.10
	MyMathLab	30	72.30	15.71
	TOTAL	97	69.22	19.14

Table 2.

Mean Final Course Grade (in GPA units) of students who took Intermediate Algebra one

semester afte	r Introduction	to Algebra	by Class Section

Class Section	N	Mean Grade	<u>SD</u>
Control	6	1.33	1.21
Tutoring Center	15	1.40	1.29
MyMathLab	16	2.25	1.23
TOTAL	37	1.76	1.30

Note. Mean Grade in GPA units, with A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, B- = 2.7, C+ = 2.3, C = 2.0, C- = 1.7, D+ = 1.3, D = 1.0, D- = 0.7, and F = 0.

Figure 1.



