

Journal of Mathematics Education at Teachers College

Fall – Winter 2011

A CENTURY OF LEADERSHIP IN
MATHEMATICS AND ITS TEACHING

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Layout

Ms. Sonja Hubbert

Photo Editor and Cover Design

Mr. Mark Causapin

Dr. Robert Taylor was selected by the Teachers College sponsored Teachers for East Africa program to teach mathematics of Uganda's Makerere University. He returned to TC as an instructor in the Department of Mathematics, Statistics, and Computing in Education where he developed an innovative programming language (FPL) intended to introduce educators to the then-new field of computer programming. His seminal work entitled *Computers: Tutor, Tool, Tutee* led to leadership in the new field of computers in education. Dr. Taylor completed 33 years as a member of the Teachers College faculty in 2009.

Dr. Carl N. Shuster completed the doctorate at Teachers College in 1940 under the guidance of William David Reeve. Shuster joined the TC faculty at Reeve's invitation and soon was recognized as the nation's leading advocate of the use of traditional technology, especially measurement technology, in the mathematics classroom. Dr. Shuster served as President of the National Council of Mathematics from 1946 to 1948 and concluded his career as Distinguished Professor of Mathematics at Trenton State University.

Aims and Scope

The *JMETC* is a re-creation of an earlier publication by the Teachers College Columbia University Program in Mathematics. As a peer-reviewed, semi-annual journal, it is intended to provide dissemination opportunities for writers of practice-based or research contributions to the general field of mathematics education. Each issue of the *JMETC* will focus upon an educational theme. The themes planned for the 2012 Spring-Summer and 2012 Fall-Winter issues are: *Evaluation* and *Equity*, respectively.

JMETC readers are educators from pre K-12 through college and university levels, and from many different disciplines and job positions—teachers, principals, superintendents, professors of education, and other leaders in education. Articles to appear in the *JMETC* include research reports, commentaries on practice, historical analyses and responses to issues and recommendations of professional interest.

Manuscript Submission

JMETC seeks conversational manuscripts (2,500-3,000 words in length) that are insightful and helpful to mathematics educators. Articles should contain fresh information, possibly research-based, that gives practical guidance readers can use to improve practice. Examples from classroom experience are encouraged. Articles must not have been accepted for publication elsewhere. To keep the submission and review process as efficient as possible, all manuscripts may be submitted electronically at www.tc.edu/jmetc.

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Math Is Not a Spectator Sport: The Effect of Online Homework-Completion Tutoring On Community College Remedial Mathematics Performance

Alice W. Cunningham
Olen Dias
Nieves Angulo

Hostos Community College, City University of New York

This article analyzes the findings from an 18-section experiment studying the effect of homework-completion tutoring on community college students' remedial mathematics performance. The experiment involved 529 students registered for two remedial math courses: math skills and algebra. For each course, the experiment studied nine sections: three experimental with multiple tutors for online homework, three control with a single tutor for online homework, and three control with a single tutor for pencil-and-paper exercises. While state budget constraints delayed the availability of tutors for the experimental group until midway through the semester, that group outperformed the pencil-and-paper group at a 0.05 significance level, while the performance of the online homework control group categories surpassed those of the corresponding pencil-and-paper categories at up to a 0.001 significance level. In addition, for each course, math lab attendance for both the experimental and control online homework cohorts surpassed that of the pencil-and-paper cohorts. These results corroborate and extend earlier research and show the importance of active problem-solving rather than passive absorption in increasing remedial mathematics performance.

Keywords: mathematics; education; remedial; developmental; community college; online homework; tutoring; small-group; attendance; problem-solving.

Introduction

This paper presents the results of an 18-section experiment conducted during the fall 2010 semester regarding the impact of small-group homework-completion tutoring on the performance of Community College's remedial mathematics students. The research was performed pursuant to a grant, *Improving Undergraduate Mathematics Learning: The Effect of Small-Group Homework Tutoring on Remedial Mathematics Learning*, from the University's Central Office of Academic Affairs. Permission from the College's Institutional Review Board was granted for the conduct of the experiment and the dissemination of the results.

The Community College is part of a large northeastern urban university, with over 260,000 degree-seeking students at multiple schools, including 6 community colleges. In accordance with its mission, "to meet the higher educational needs of people...who historically have been excluded from higher education" (Community College, 2010), the College attracts the weakest of these students. Close to 90% of all students enter needing remediation in at least one of the three subjects of reading, writing, and mathematics (Office of Institutional Research, 2011). Uniformly, three-quarters of all entering students require remediation in mathematics, while one-third (constituting one-half of the entire university's total population in this category, University Mathematics

Council, 2011) require remediation in all three subjects (Office of Institutional Research, 2011). As of the fall 2010 semester, the College's population was approximately 60% Hispanic, 28% black, and 68% female (Office of Institutional Research, 2011).

The mathematics classes in question are the two courses, Basic Math Skills (Math 010), and Elementary Algebra (Math 020) directed toward passing the two levels of the CUNY-wide COMPASS exit test (M1 and M2) necessary for college level work. Such courses meet four days per week, three times with an instructor and the fourth with a tutor. Traditionally, the tutor-led meeting, called the Math Lab, has followed one of two formats: (1) using departmentally-prepared pencil-and-paper exercises related to that week's class-work or (2) using Pearson Publishing's MathXL interactive online textbook-based homework assignments.

This experiment focused on the tutoring component of the two remedial mathematics courses. Prior research indicates that small-group homework-completion tutoring improves student performance not only in the current but in subsequent mathematics courses (e.g., Hagedorn, Sahger, & Siadhat, 2000; Perrin, 2004; Harootounian & Quinn, 2008). In addition, an earlier Community College study showed the efficacy for mathematics performance of using the online MathXL homework vehicle to support student homework completion (Menil & Author, 2008). Thus, we hypothesized that having additional tutors available in the weekly Math Lab meeting of each course

to lower the tutor/student ratio would facilitate the students' completion of their online homework, improving their performance on both the COMPASS exit test and in class. Moreover, because mathematics learning is cumulative (e.g., National Academy of Education, 2009; National Mathematics Advisory Panel, 2008; National Research Council, 2001), and requires active student problem-solving rather than passive note-taking (e.g., Hinds, 2009; Menil & Author, 2008), we took the view that assistance in completing assigned homework as soon as possible after each class was particularly important. Thus, the tutoring component of the course constituted the independent variable, and COMPASS performance and final class grades the dependent variables. Additional factors studied included gender, ethnicity, and Math Lab attendance. These issues are important, as difficulty completing mathematics courses constitutes a significant contributing factor to low graduation rates, both at the University (e.g., Hinds, 2011; Hinds, 2009; Community College, 2008) and nationwide (Biswas, 2007). This paper reports our findings.

Method

Study Design

As each of the participating students self-selected the respective sections through online registration without previous knowledge of the experiment, the research reflects a quasi-experimental design (DePree, 1998). The research involved 18 sections, 9 for each of the two remedial courses. Of those nine, six (three experimental with five tutors per section and three control with one tutor per section), used the Math Labs for MathXL homework-completion tutoring. The remaining three of the nine

sections for each course, again with one tutor each, used the Math Labs for the departmentally-prepared pencil-and-paper exercises. Thus, for each of the two remedial courses, the Math Lab classes involved three experimental sections with multiple tutors using MathXL (E), three control sections with the traditional single tutor using MathXL (C1), and three control sections with the traditional single tutor using pencil-and-paper exercises (C2).

Classes ranged in size from 27-30 students. For the Basic Math Skills course, the experimental sections had 89 students, the C1 sections had 90 students, and the C2 sections had 86 students, for a total of 265 students. For the Elementary Algebra course, the three experimental sections had 88 students, the C1 sections had 89 students, and the C2 sections had 87 students, for a total of 264 students. Thus, overall, the experiment involved 529 students, of whom 177 (or 33.5%) were in the two experimental cohorts.

Data were collected regarding the gender and ethnic background of the students, as well as the number of their previous attempts at passing the COMPASS exit exam. Approximately 10% of the students were under the age of 18. As the College IRB required documentation of student consent only for those students under the age of 18, no data were collected regarding the ages of the remaining students.

In order to control for teaching variations, each of the pairs of sections using online homework completion tutoring (E and C1) was taught during early morning hours by the same full-time daytime instructor. The pencil-and-paper sections were taught, again during early morning hours, primarily by adjunct instructors. The experiment involved 7 full-time and 4 adjunct instructors, for a total of 11 instructors. With one exception, all of the instructors had substantial previous experience in teaching their respective courses.

Table 1. Average percentages of Math 010 COMPASS certification and pass rates

Groups	Certification Rate	Certified COMPASS Pass Rate	Whole Class COMPASS Pass Rate
Experimental (89 students)	51%	67%	35%
Control-1 (90 students)	56%	81%	43%
Control-2 (86 students)	45%	52%	24%

Table 2. Average percentages of Math 020 COMPASS certification and pass rates

Groups	Certification Rate	Certified COMPASS Pass Rate	Whole Class COMPASS Pass Rate
Experimental (88 students)	53%	57%	31%
Control-1 (89 students)	52%	73%	38%
Control 2 (87 students)	62%	69%	43%

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Study Effectuation

Due primarily to state budget constraints that delayed receipt of the grant funding, the research was not conducted entirely in accordance with its design. While both sets of control sections (C1 and C2) had tutors available for the Math Lab sections by the 3rd week of the 14-week semester, tutors for the experimental sections were not available until the 6th week of that semester. Therefore, the Math Lab tutors supplied to both sets of control sections came from a pool of pre-existing tutors, all with previous experience in teaching the respective courses, and many with higher-level credentials. By contrast, the new tutors were drawn primarily from newly-hired Community College students working towards their own degrees and therefore with no previous experience in teaching these or other courses. Finally, again because of the delay in hiring the experimental tutors, training by Pearson Publishing of the tutors in the use of the online homework was deferred from before the beginning of the semester until midway through the semester (the 7th of 14 weeks) and occurred just once rather than twice.

Results

Performance on the COMPASS Exit Test

Basic Math Skills. Table 1 sets forth the results for this course. The table reflects three comparisons for the experimental and two control groups: the COMPASS certification rate, the COMPASS pass rate of those students certified, and the COMPASS pass-rate of the whole class. (Instructors determine their students' eligibility, or certification, to take the COMPASS based primarily on the students' scores on a departmental midterm designed for this purpose.) In each instance, although the C1 group performed better than the experimental group (56% v. 51%

certified; 81% v. 67% certified pass rate; and 43% v. 35% whole-class pass rate), the experimental group uniformly outperformed the C2 (pencil-and-paper) group (51% v. 45% certified; 67% v. 52% certified pass rate; and 35% v. 24% whole-class pass rate). Thus, the data strongly support not only the efficacy of student problem-solving using interactive online homework software, but also the importance of beginning homework-completion assistance as early in the semester as possible.

Elementary Algebra. Table 2 sets forth the results for this course. The results for the upper level remedial course are less probative. Although the experimental group outperformed the C1 groups in terms of the COMPASS certification rate (53% v. 52%), both the COMPASS pass rates of those students certified (57% E v. 73% for C1 and 69% for C2) and of the whole class (31% E v. 38% for C1 and 43% for C2) were higher for the two control groups than for the experimental group.

Analysis of COMPASS Exit Test Performance Results

Without taking into account the delay in the provision of tutors and the differential experience level of those tutors for the experimental cohorts for both courses, the C1 groups (using online homework with a single tutor) performed better than the experimental groups (using such homework with multiple tutors). For Elementary Algebra, the results are substantially similar. Most importantly from the standpoint of the importance of the homework completion tutoring being tested in this study, however, in Basic Math Skills the multiple-tutor online homework groups outperformed the pencil-and-paper exercise groups notwithstanding the experimental tutors' later start date and lesser teaching experience.

As shown by Table 3, the experimental groups' increased performance occurred in all three categories:

Table 3. Performance comparison of experimental and pencil-and-paper lab groups

GROUPS	Certification Rate	Certified COMPASS Pass Rate	Class COMPASS Pass Rate
Experimental (n = 89)	51%	67%	35%
Control-2 (n = 86)	45%	52%	24%
Percentage point difference	6 percentage points	15 percentage points	11 percentage points
Percent difference	$(51-45) / ((51+45)/2) = 6/48 = .125 = 13\%$	$(67-52) / ((67+52)/2) = 15/59.5 = .25 = 25\%$	$(35-24) / ((35+24)/2) = 11/29.5 = .37 = 37\%$
% Diff = $\left \frac{x_1 - x_2}{(x_1 + x_2)/2} \right \times 100$			
P-value	0.201	0.028	0.0484
Significance	$N_1 = 89 \quad X_1 = 46$ $N_2 = 86 \quad X_2 = 39$ Not Significant	$N_1 = 89 \quad X_1 = 60$ $N_2 = 86 \quad X_2 = 45$ Significant at 0.05 level	$N_1 = 89 \quad X_1 = 32$ $N_2 = 86 \quad X_2 = 21$ Significant at 0.05 level

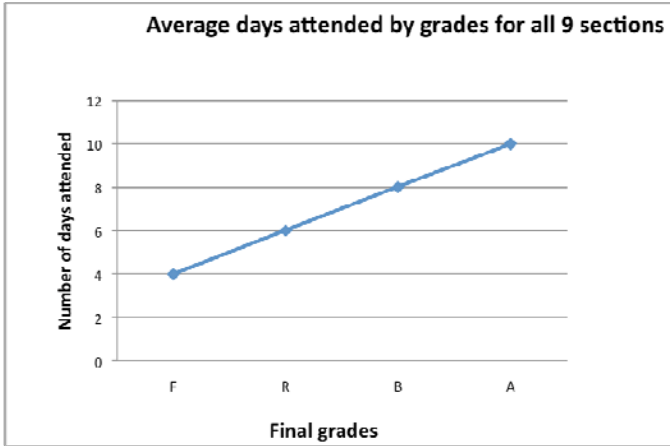


Figure 7. Basic Math Skills Math Lab attendance by final grade

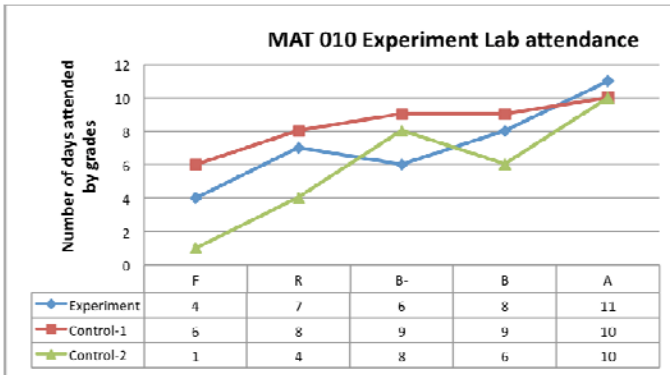


Figure 8. Basic Math Skills Math Lab attendance by cohort

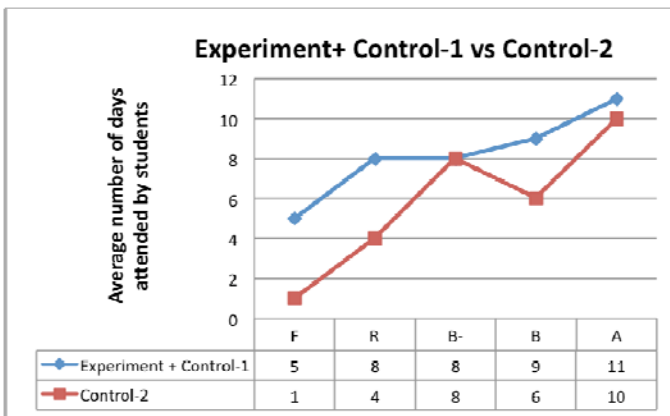


Figure 9. Basic Math Skills Math Lab Attendance by online and pencil-and-paper cohorts

certification rate; certified COMPASS pass rate; and whole-class pass rate. Specifically, the experimental group’s certification rate was 13% higher than the C2 certification rate. Similarly, the experimental group’s certified COMPASS pass rate was 25% higher than the C2 pass rate, while the

experimental group’s whole-class COMPASS pass rate was 37% higher than the C2 pass rate. As show by Table 3 above, using a right-tailed z-test of significance, both pass rate differences are significant at a 0.05 level.

When comparing the two control groups, which both started their math labs only three weeks into the semester, the Basic Math Skills COMPASS results are even more striking. As shown by Table 4, the C1 homework-tutored group dramatically outperformed the pencil-and-paper group in all three categories: certification rate, certified pass rate, and whole-class pass rate. Again using a right-tailed z-test, this percentage difference is significant for the first category at a 0.10 level, for the second at a 0.001 level, and for the third at a 0.01 level.

The same pattern did not hold true for Elementary Algebra, where both the online homework and the pencil-and-paper control groups outperformed the experimental group. Nevertheless, the Basic Math Skills result, showing across-the-board improved performance for the homework-tutored groups, both corroborates earlier research on this issue (Menil & Author, 2008) and strongly supports the importance to remedial mathematics performance of homework completion tutoring begun as early in the semester as possible.

Additional Performance Indicators

Final Grades, Gender, and Ethnicity

For both Basic Math Skills and Elementary Algebra, final course grades, gender, and ethnicity are non-predictive in favor of one cohort over another. (Detailed data analyses are available upon request.) Thus, these data permit no generic conclusions regarding the tutoring method best calculated to improve remedial mathematics performance.

Math Lab Attendance

Lab attendance is another matter, however. Data for both Basic Math Skills and Elementary Algebra reflect the strong relationship between Math Lab attendance and performance. More importantly, these data reflect stronger attendance, with correspondingly better grades, for both the single and multiple homework tutoring sections (the E and C1 cohorts) than for the pencil-and-paper exercise sections (the C2 cohort).

Basic Math Skills. Figure 7 shows Math Lab attendance by grades for all nine sections combined (three each for E, C1, and C2). Figure 8 compares attendance by grade for each of the three cohorts considered separately, while Figure 9 contrasts attendance by grade for the combined online homework-completion cohorts (E and C1) with the pencil-and-paper cohort (C2).

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Table 4. Performance comparison of MathXL and pencil-and-paper control groups

GROUPS	Certification Rate	Certified COMPASS Pass Rate	Class COMPASS Pass Rate
Control-1 (n = 90)	56%	81%	43%
Control-2 (n = 86)	45%	52%	24%
Percentage point difference	11 percentage points	29 percentage points	19 percentage points
Percent difference	$(56-45) / ((56+45)/2)$	$(81-52) / ((81+52)/2)$	$(43-24) / ((43+24)/2)$
$\% \text{ Diff} = \left \frac{x_1 - x_2}{(x_1 + x_2)/2} \right \times 100$	$= 11/50.5 = .22$	$= 29/66.5 = .44$	$= 19/33.5 = .57$
	=22%	=44%	= 57%
P-value	0.066	0.0000244	0.004
Significance	N ₁ = 90 X ₁ = 51 N ₂ = 86 X ₂ = 39 Significant at 0.10 level	N ₁ = 90 X ₁ = 73 N ₂ = 86 X ₂ = 45 Significant at 0.001 level	N ₁ = 90 X ₁ = 39 N ₂ = 86 X ₂ = 21 Significant at 0.01 level

As indicated, the data reflect both the positive relationship between Math Lab attendance and final course grades, and the increased Math Lab attendance by students in the online homework tutoring Math Lab sections as compared to the pencil-and-paper Math Lab sections. The latter result appears both when comparing the three cohorts separately and when contrasting the combined online homework-completion tutoring cohorts (E and C1) with the pencil-and-paper exercise cohort (C2). Thus, the Math Lab attendance data for Basic Math Skills suggest a strong student preference for online homework-completion tutoring over pencil-and-paper exercises.

Further support for this result is shown by Table 5. Considering both the E and C1 online homework tutoring cohorts combined, this table demonstrates a positive linear correlation between grades and lab attendance (using a linear regression t-test) significant at the .01 level.

Elementary Algebra. The same holds true for Elementary Algebra. Figure 10 compares Math Lab

attendance by final grade for all nine sections combined (three each of E, C1, and C2). Figure 11 compares Math Lab attendance by final grade for each of the three cohorts taken separately, while Figure 12 contrasts Math Lab attendance by final grade for the combined online homework-completion cohorts (E and C1) with the pencil-and-paper cohort (C2).

As in the case of Basic Math Skills, the evidence supports two findings. First, final course grades show a positive relationship with Math Lab attendance. Secondly, cohorts using their Math Labs for online homework-completion tutoring, whether by single or multiple tutors, show greater Math Lab attendance whether the online cohorts are considered separately or together. Again as in the case of Basic Math Skills, these results are supported by Table 6, which shows a positive linear correlation significant at the 0.01 level for the two online homework tutoring cohorts taken together.

Table 5. Basic Math Skills grade/lab attendance correlation (r: linear correlation coefficient)

Grades	A	B	B-	R	F	P-value = 0.0064 r = 0.969	p < 0.01
E + C1	11	9	8	8	5		
Grades	A	B	B-	R	F	P-value = 0.036 r = 0.9025	p < 0.05
C2	10	6	8	4	1		

Table 6. Elementary Algebra grade/lab attendance correlation (r: linear correlation coefficient)

Grades	A	B	B-	R	F	P-value = 0.003 r = 0.981	p < 0.01
E + C1	9	8	7	7	5		
Grades	A	B	B-	R	F	P-value = 0.16 r = 0.73	Not significant
C2	6	2	4	2	1		

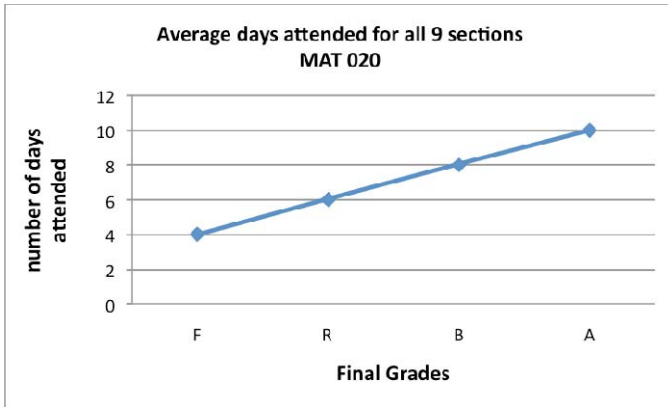


Figure 10. Elementary Algebra Math Lab attendance by final grade

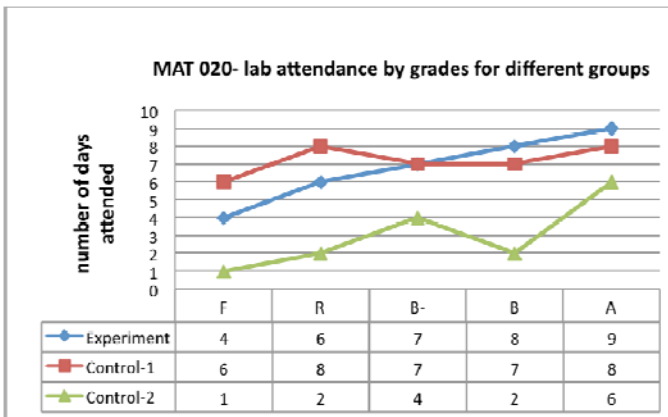


Figure 11. Elementary Algebra Math Lab attendance by cohort

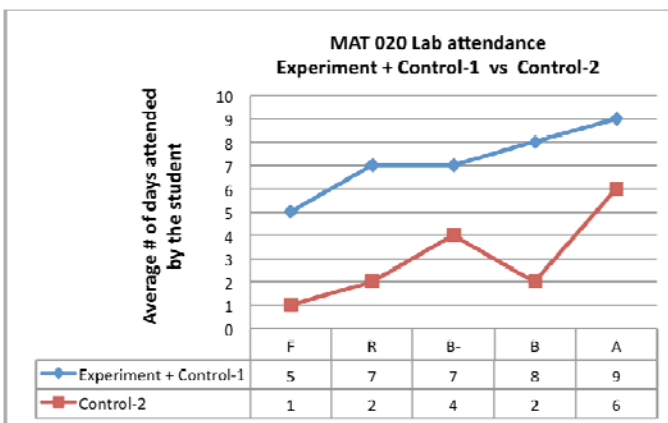


Figure 12. Elementary Algebra Math Lab attendance by online and pencil-and-paper cohorts

Analysis of the student remedial mathematics performance by final course grade, gender, and ethnicity offers little insight into the respective effectiveness of online homework-completion tutoring or pencil-and-paper exercises in the remedial courses' Math Labs. However, performance on the COMPASS exit test and Math Lab attendance results are another matter. As shown by Tables 3 and 4 in the case of the COMPASS results and by Figures 7-8 and 11-12 in the case of Math Lab attendance, using the Math Lab portion of the two remedial courses for online homework-completion tutoring rather than for pencil-and-paper exercises dramatically increases student attendance. For the COMPASS pass rate in Basic Math Skills, this result is significant for the experimental online homework tutoring group at the 0.05 level for both the certified- and whole-class pass-rate categories (Figure 3), even though the experimental group received its full complement of tutors three weeks later into the semester than did both control groups. For the C1 online homework tutoring group, the results are even more striking, reflecting increased performance for the certification category at a 0.10 significance level, for the certified pass-rate category at a 0.001 significance level, and for the whole-class pass-rate category at a 0.01 significance level. As for attendance, that aspect of student performance is higher in each course for both the experimental and C1 online homework tutoring groups than for the C2 pencil-and-paper group (Figures 7-8, 11-12), with a corresponding correlation in grade improvement in each course significant at a 0.01 level (Tables 5 and 6). These results thus both corroborate and extend earlier research performed at Hostos (Menil & Author, 2008) showing the efficacy for remedial mathematics students of online homework tutoring.

Conclusion

To some extent, the results of our online homework-completion experiment are not as robust as we might have liked. In terms of COMPASS results, the single-tutor online homework groups outperformed the multiple-tutor online homework groups in both COMPASS pass-rate categories (certified and whole class). These conclusions could be interpreted to suggest that a single tutor is more effective than multiple tutors for homework-completion assistance in the two remedial math courses' Math Labs.

Nevertheless, we regard our results as pointing in the other direction. Mathematics learning is cumulative. Due to the state budget constraints that delayed the provision of tutors to the experimental group, students in the experimental cohort were unable to obtain the full benefit of the Math Lab tutoring classes. Because the cohorts which received homework tutoring earlier in the semester

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outperformed those receiving such tutoring only later in the semester, we believe that our results support the importance for remedial mathematics students of homework-completion tutoring, the earlier begun, the better.

More importantly, notwithstanding the delay in the provision of tutors to the experimental cohort and those tutors' lack of previous teaching experience, our COMPASS results in the Basic Math Skills course show the homework-tutored experimental group significantly outperforming the pencil-and-paper group in each pass-rate category (certified- and whole-class pass rate), thus supporting the appeal of interactive online homework. Our Math Lab attendance data point to a similar conclusion. Math is not a spectator sport. Assistance with online homework completion that engages student interest in active problem-solving rather than in mere passive note-taking will further increase remedial mathematics performance.

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Journal of Mathematics Education at Teachers College

Call for Papers

The “theme” of the fall issue of the *Journal of Mathematics Education at Teachers College* will be *Evaluation*. This “call for papers” is an invitation to mathematics education professionals, especially Teachers College students, alumni and friends, to submit articles of approximately 2500-3000 words describing research, experiments, projects, innovations, or practices related to evaluation in mathematics education. Articles should be submitted to Ms. Krystle Hecker at JMETC@tc.columbia.edu by January 21, 2012. The spring issue’s guest editor, Ms. Heather Gould, will send contributed articles to editorial panels for “blind review.” Reviews will be completed by February 1, 2012, and final drafts of selected papers are to be submitted by March 1, 2012. Publication is expected by April 15, 2012.

Call for Volunteers

This *Call for Volunteers* is an invitation to mathematics educators with experience in reading/writing professional papers to join the editorial/review panels for the spring 2012 and subsequent issues of *JMETC*. Reviewers are expected to complete assigned reviews no later than 3 weeks from receipt of the manuscripts in order to expedite the publication process. Reviewers are responsible for editorial suggestions, fact and citations review, and identification of similar works that may be helpful to contributors whose submissions seem appropriate for publication. Neither authors’ nor reviewers’ names and affiliations will be shared; however, editors’/reviewers’ comments may be sent to contributors of manuscripts to guide further submissions without identifying the editor/reviewer.

If you wish to be considered for review assignments, please request a *Reviewer Information Form*. Return the completed form to Ms. Krystle Hecker at hecker@tc.edu or Teachers College Columbia University, 525 W 120th St., Box 210, New York, NY 10027.

Looking Ahead

Anticipated themes for future issues are:

Spring 2012	Evaluation
Fall 2012	Equity
Spring 2013	Leadership
Fall 2013	Modeling
Spring 2014	Teaching Aids

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