Efficacy Report

MyMathLab for Developmental Mathematics

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Product Summary

MyMathLab is an online tutorial and assessment tool for teaching and learning mathematics. It is designed to provide engaging experiences and personalized learning for each student so that each can succeed. MyMathLab's tutorial exercises regenerate algorithmically to give students multiple opportunities for practice on varying content. The exercises include immediate feedback when students enter answers, which research indicates strengthens the learning process (Bangert-Drowns, Kulik, Kulik, & Morgan,1991; Hattie, 2009; Hattie & Timperley, 2007; Sadler, 1989). MyMathLab also has several types of adaptive learning resources - adaptive study plan and companion study plan assignments -to support personalized learning. MyMathLab automatically tracks students' results, and includes item analysis to track class-wide progress on specific learning objectives. MyMathLab is intended to make a measureable impact on defined learner outcomes related to educational access, completion, competence, and progression. By providing every student a personalized remediation plan through the material and tracking progress at the objective level, MyMathLab effectively lowers the student to instructor ratio - a feature that is especially important for the success of developmental mathematics students.

Intended Outcomes

Overview of Intended Outcomes

One of the biggest challenges that colleges in the US face is that many students enter college unprepared to complete college-level mathematics courses. Most colleges have a sequence of developmental mathematics courses that start with basic arithmetic and then go on to pre-algebra, elementary algebra, and finally intermediate algebra, all of which must be passed before a student can enroll in a credit-bearing college mathematics course. MyMathLab is designed to provide students with a positive learning experience and develop a positive mindset to math so that they can achieve prerequisite math skills that will allow them to enroll in and successfully complete credit-bearing mathematics courses.

Intended Outcome 1: Learners have a positive learning experience
MyMathLab is designed to provide students with a positive learning experience. A variety of multimedia resources are available as assignment learning aids. Students can link to the ebook, video clips, and animations to improve their understanding of key concepts.

Intended Outcome 2: Learners have a positive mindset to math
There are a variety of motivations, beliefs, and attitudes that may prevent students from achieving their potential. Specifically, three areas of importance are: dealing with anxiety, personal relevance, and mindset. These are areas where MyMathLab is aiming to help students, and mindset is a key outcome validated by instructors as being of importance to them and their students.

Intended Outcome 3: Learners complete tasks / activities / course on time
All required parts of the course must be completed and passed before a student can go onto the next stage in his or her learning. Most exercises in MyMathLab include learning aids, such as guided solutions, sample problems, and extra help at point-of-use, and also offer helpful feedback when students enter incorrect answers all designed to help students complete their assigned work.

Intended Outcome 4: Learners improve in skills
The adaptive study plan and companion study plan assignments support personalized learning updating in real time based on student performance throughout the course to provide personalized recommendations on what students should work on next, which enable students to practice and improve specific skills.

Intended Outcome 5: Learners complete the course / retained to end of course
Most colleges in North America have a sequence of developmental mathematics courses that start with basic arithmetic and then go on to pre-algebra, elementary algebra, and finally intermediate algebra, all of which must be completed and passed before a student can enroll in a credit-bearing college mathematics course.

Foundational Research

Overview of Foundational Research

MyMathLab is aligned with the insights gained from over 30 years of research into intelligent tutoring systems (e.g., Ohlsson, 1986; Anderson, Corbett, Koedinger & Pelletier, 1995). In particular, it helps students to turn the knowledge they gain, in class and through studying their textbook, into procedural fluency by offering extensive and well-supported practice (Anderson & Schunn, 2000). This process of developing expertise is supported by offering immediate feedback, providing different kinds of support (i.e., worked examples, hints), by helping to focus students' attention on critical elements, and manage their load on working memory (Sweller & Cooper, 1985). All of these strategies and features are intended to enable students to succeed, often for the first time, in math, and so they begin to develop a positive mindset to mathematics, leading to more success.

MyMathLab contextualizes all help functionality for developmental math students to help them succeed at solving the problem at hand. It is crucial for these students to establish a pattern of success in mathematics, and the contextualized learning aids in MyMathLab help guide students to begin a positive journey through the material.

Mindset
In educational psychology research, there are a number of research areas that deal with understanding the motivations, beliefs, and attitudes that may prevent students from achieving their potential, and that detail strategies for helping students adjust those non-cognitive factors. Specifically, three areas of importance are: dealing with anxiety (Maloney & Beilock, 2012), personal relevance (Hulleman, Godes, Hendricks, & Harackiewicz, 2010), and mindset (Dweck, 1996). These are areas where MyMathLab is aiming to help students, and mindset is a key outcome validated by instructors as being of importance to them and their students.

A growing body of research has found that there are benefits associated with adopting a growth mindset. Students with a growth mindset are more likely to adopt more learning-oriented goals, to persist longer (Diener & Dweck, 1978), to use better learning strategies, and, ultimately, to achieve better grades (Yeager & Dweck, 2012).

Key features of the research into learning design for MyMathLab are:

Scaffolding with worked examples
There are a variety of learner support tools to help students struggling with assessment items (hints, videos, animations, e-text), and students can "ask for help" and get step-by-step support in solving a math problem (Sharma & Hannafin, 2007).

Feedback
MyMathLab enables students to check frequently on their understanding and receive immediate feedback, which is one of the most effective means for building long-term retention and increasing student confidence and motivation (Hattie 2009, 2012). Feedback provided in association with practice activities in MyMathLab is specific, clear, concise, and timely.

Instructors see basic student performance (e.g., number of items correct/incorrect, attempted) on assignments, and students can see detailed performance on specific learning objectives.

Cognitive load

In cognitive psychology, cognitive load refers to the total amount of mental effort being used in working memory (Miller, 1956). This includes extraneous cognitive load (the mental effort spent on distracting elements that are not relevant to the learning). Research shows that if you can reduce extraneous cognitive load for students when they are reading or studying, you can improve the effectiveness of learning (Sweller, 1988). Put simply, if you remove distractions, learning is more likely to occur. In MyMathLab, extraneous cognitive load is kept low through the following approaches: topics and subtopics are organized coherently into manageable chunks, assessments are presented in a clean area, and the e-text is accessible and easy to read.

Adaptivity

Research has identified two types of adaptivity in learning technologies. One type relates to adaptive responses to students (i.e. adaptive feedback). Similar to the research described above about feedback, adaptive systems that provide timely feedback to students as they engage with the learning technology have been shown to be as effective as human tutors (VanLehn, 2011).

The other mode of adaptivity relates to adapting a learning sequence based on an understanding of a student's current proficiency. One way in which this can be done is by estimating mastery understanding of skills and concepts based on student performance, and ensuring that students receive enough practice to achieve fluency with the content. This 'Knowledge Tracing' has been used to great effect (Corbett & Anderson, 1995). MyMathLab uses the latest advances in adaptive learning technology, offering two options--the Adaptive Companion Study Plan and Personalized Homework. Instructors have the flexibility to incorporate the style and approach of adaptive learning that best suits their course structure and students' needs.

Intended Product Implementation

Overview of Intended Product Implementation

Over the past 10 years, educator studies completed by Pearson's customers have reported a variety of approaches to the implementation of MyMathLab for Developmental Math. Within blended instruction models, students use MyMathLab for Developmental Math to complete assigned reading and homework prior to class lectures and may then also complete chapter quizzes that account for 10% to 60% of their course grade. In the emporium model, students use MyMathLab for Developmental Math in computer labs or computer classrooms staffed by instructors, professional tutors, and/or peer tutors. Students progress through the course material at their own pace and may receive one-on-one assistance when they encounter difficulties in learning the material or progressing within the course. In hybrid programs that incorporate traditional lectures and the extensive use of technology, students attend a set amount of lectures per week and then spend time in a computer lab or on their own working with MyMathLab for Developmental Math, combining self-paced and guided instruction to complete online assignments and assessments. While educators who have used each of these implementation approaches have reported success with the use of MyMathLab for Developmental Math, more robust studies are needed to identify the combination of implementation approaches and use patterns for MyMathLab for Developmental Math that are associated with different levels of learner outcomes.

Product Research

Overview of Product Research

Over the past 10 years, instructors that have used MyMathLab for Developmental Math have produced 63 educator studies, describing how they implemented the product in their courses and how using MyMathLab for Developmental Math has impacted their instruction and their student learning outcomes.

In the majority of the educator studies, instructors have generally reported increased engagement and positive learning experiences with use of the product among their students. Also, most of the educator studies report increased completion rates, and most of the studies include data showing higher test scores and pass rates for students enrolled in the course following the implementation of MyMathLab for Developmental Math. Educator studies are designed and implemented by the course instructor and do not use experimental or quasi-experimental designs that could robustly attribute the changes in learner outcomes to MyMathLab for Developmental Math. For this reason, exact figures around noted increases are not included in this paragraph.

Pearson researchers completed a systematic search and review of published, peer-reviewed studies that assessed the impact of MyMathLab for Developmental Math on learner outcomes with more rigorous designs than educator studies; 24 studies on MyMathLab for Developmental Math are published in education journals, conference proceedings, or as doctoral dissertations. Among these, two studies (one correlational study and one quasi-experimental study) used rigorous methodology that provide reliable evidence about the relationship between the use of MyMathLab for Developmental Math and learner outcomes.

About the claims included in this report

In reporting causal claims about the impact of our products on learner outcomes, Pearson relies on guidance by the US Department of Education What Works Clearinghouse (WWC) to determine which available studies have been conducted and reported using the following standards of research that would yield valid and reliable information.

- **Research design.** In accordance with WWC standards, we focused on randomized controlled trials, quasi-experimental designs, regression discontinuity designs and single case designs. If conducted properly, these are the research designs that are of sufficient rigour to allow us to make causal claims.
- **Attrition.** Using WWC guidance, we considered both overall and differential attrition - the extent to which both users and non-users of the Pearson product remain in the study - in relation to each other to determine if we could use the results from the studies.
- **Baseline equivalence.** Equivalence of the intervention and comparison groups on observable characteristics at baseline must be presented for the analytic sample in order

for us to draw valid conclusions about the extent to which changes in student outcomes could be reliably and validly attributed to use of the Pearson product.

- **Outcomes eligibility.** Outcomes examined in the studies must have validity and of sufficient reliability for us to use the results from the outcomes. These outcomes must also be aligned to Pearson's defined learner outcomes. There must also be no over-alignment of the outcomes to the Pearson product and data collection (i.e, the outcomes must be done in the same manner for both the treatment and control groups.

Our search and review process for evidence of impact provided by independent and published studies

The search for external studies on a particular Pearson courseware product was done primarily through Google Scholar and the rest were found through snowballing from relevant articles on the Pearson product. In Google Scholar, the keyword of the Pearson product was used before a scan of the title and abstract was done to determine relevance. No studies earlier than 2008 were reviewed since they were probably based an outdated version of the Pearson product. Articles that discussed implementation but did not examine any Pearson defined learner outcomes on a population in higher education were also excluded.

During our review process, it was found that some of the quasi-experimental studies did not examine baseline differences at all. Others were of slightly higher rigour in that prior differences were examined or acknowledged but no attempts were made to take into account these prior differences in the analysis. Thus, we would consider these studies correlational and not studies that can lead to causal claims.

The next level of better designed studies were those that tried to control for prior differences of students in some way, such as through regression analysis or ANCOVA. Other studies used random assignment. However, many of these quasi-experimental or randomized studies assigned the treatment or control condition at the class level but failed to consider clustering at the class/instructor level when there were multiple instructors involved in the study. Thus, the potential confounding effects of instructors on student achievement were not taken into account in these studies. As a result, in most cases, the estimates of the statistical reliability of the impact estimates from these studies are incorrect and misleading, leading readers to believe they should have more confidence in the results than warranted. Thus, in summary, the studies that could be used to make causal claims were those that used a rigorous research design, had acceptable overall and differential attrition rates, addressed baseline equivalence, and used the right method of analysis.

Research Studies

Undergraduate Students' Knowledge of Algebra: Evaluating the Impact of Computer-Based and Traditional Learning Environments	
Study Citation	Krupa, E. E., Webel, C., & McManus, J. (2015). Undergraduate students' knowledge of Algebra: Evaluating the impact of computer-based and traditional learning environments. *PRIMUS, 25*(1), 13-30.
Research Study Contributors	Faculty at Montclair State University
Type of Study	Quasi Experimental Design
Sample Size	123 students
Description of Sample	The students in the study were enrolled in the Intermediate Algebra course at Montclair State University, which is the first course in the credit-bearing mathematics sequence that would prepare students for pre-calculus. Thus, the sample is limited to students at one university.
Outcomes Measured	The learner outcome is the final exam score.

Introduction
The study explored the impact of two types of instructional settings, face to face versus computer-based, on student learning.

Method
Participants in the study were students from a mid-sized suburban university on the east coast. Students were enrolled in the Intermediate Algebra course which is the first course in the credit-bearing mathematics sequence and it would prepare students for pre-calculus.

The study is a quasi-experimental study, where students enrolling in one of the twelve sections of the course did not know at the time of enrollment which instructional setting they would be in. Half of the courses offered for that semester were given in the computer-based (CB) environment while the other half were in the face-to-face (F2F) environment. Instructors of the F2F courses used E. Martin-Gay's *Intermediate Algebra (Sixth Edition)* and could teach the course in anyway as long as they covered the required topics. The CB courses were conducted emporium-style and used the same text along with MyMathLab for Developmental Math. Students in the CB course worked through the course content online and were also required to attend normal class hours at the mathematics computer lab on campus, but could proceed through the textbook as they passed quizzes and tests they took in the lab.

A total of 326 students enrolled in one of the 12 sections of the Intermediate Algebra course (CB n = 134, F2F n = 192). Of these enrolled students, 123 provided the research team with access to student-level predictors including—SAT math scores, high school GPA, Algebra II grade, and college GPA. This study examined the final exam scores, taking into account student-level predictors as covariates, of students (n=73) enrolled in the CB courses compared to students (n=50) enrolled in the F2F courses in Spring 2012.

Results

It was observed that, for students with high prior math ability, use of MyMathLab in a CB environment resulted in higher final exam scores than no use of MyMathLab in a F2F environment. Conversely, students with lower prior math ability resulted in higher final exam scores in the F2F environment. Specifically, ANCOVA, with SAT math as the covariate, found that the mode of delivery was significantly related to final exam score (F=3.58, p=0.06). In addition, ANOVA found that the interaction of mode of delivery and SAT scores was a significant predictor of student achievement (F=-2.31, p=0.029), indicating that students with higher SAT math scores tended to perform better in CB setting where MyMathLab for Developmental Math was used, while student with lower SAT math scores tended to perform better in the F2F setting.

Discussion

This study is close to a randomized controlled trial because the students had no knowledge of which condition they would be in when enrolling in the course (p.17). In addition, prior achievement, in terms of SAT math scores, which is an important covariate that normally covers a big proportion of the variance in the differences between groups, was included as a covariate during the analysis.

There are a few caveats associated with the study:

First caveat--subset of students with prior achievement data. The first caveat is that only a subset of students out of all students enrolled in the course could be analyzed because only a subset of the students had provided the research team with SAT math scores.

Second caveat--limited statistical controls. The second caveat is that only SAT math scores were used as a covariate in the analysis, more covariates could have been controlled for in the analysis to make a more robust conclusion.

Third caveat--MyMathLab treatment was confounded with type of instruction. The third caveat is that the treatment was delivered emporium-style while the control had instructors teaching in a traditional way. Thus, the results we found about MyMathLab for Developmental Math is a combination of MyMathLab, plus emporium style type of instruction. As such, our conclusion for this study is limited to the impact of MyMathLab-Development delivered emporium style.

In conclusion, we can make a causal statement with this study about MyMathLab delivered emporium-style, given that an important covariate, prior achievement, was used as a covariate. However, more covariates could have been used to make the study more rigorous.

In Search for the Most Informative Data for Feedback Generation: Learning Analytics in a Data-rich Context	
Study Citation	Tempelaar, D. T., Rienties, B., & Giesbers, B. (2014). In search for the most informative data for feedback generation: Learning analytics in a data-rich context. *Computers in Human Behavior, 47*, 157-167.
Research Study Contributors	Faculty at University of Maastricht
Type of Study	Correlation
Sample Size	873 students
Description of Sample	Complete data on 873 out of 922 students in the freshmen cohort enrolled in the quantitative methods (mathematics and statistics) of the School of Business and Economics at Maastricht University were examined in this study. A large diversity of students was reported in this sample. Only 24% were educated in Dutch high schools. The largest group, 46% of the students, came from the German Abitur system. Thus, this study has a large sample with diversity, though it is only limited to one university.
Outcomes Measured	The outcomes measured were the math exam scores and the aggregate scores of three math quizzes.

Introduction

A study was conducted with freshman students enrolled in the quantitative methods of the School of Business and Economics at Maastricht University in the Netherlands. Two external e-tutorials were utilized in the course: MyStatLab and MyMathLab for Developmental Math, but for this report, we focused only on MyMathLab for Developmental Math results. Specifically, in the study, the authors examined the relationship between the frequency of use (i.e. time spent on MyMathLab for Developmental Math task and the number of attempts per MyMathLab for Developmental Math task) and students' final exam and quiz scores. In addition, this study also determined the relationship between MyMathLab for Developmental Math performance on the final exam and quizzes in the course.

The research question asked by the authors was 'To what extent do predictions based on these alternative data sources (such as learning disposition data, MyMathLab for Developmental Math data, and data from final exam and quizzes) refer to unique facets of performance, and to what extent do these predictions overlap?'

Method
Complete data on 873 out of 922 freshmen enrolled in quantitative methods (mathematics and statistics) of the School of Business and Economics at Maastricht University were analyzed in the study. Data on these students included demographic data from registration systems, diagnostics entry test data, learning disposition data obtained from surveys, user track data from the learning management system, data from MyLab (i.e. mastery scores, time on task, and number of attempts), and academic performance data (i.e. the final written exam, aggregate scores for three quizzes).

Results
Regression models were used as prediction models. Both performance on the math exam and math quizzes were positively related to mastery in MyMathLab (with regression coefficients of .67 and .80 respectively), but they were negatively related to time on tasks in MyMathLab (with coefficients of -.16 and -.15 respectively) and average number of attempts in MyMathLab (with coefficients of -.32 and -.15 respectively), when all of these MyMathLab variables were simultaneously considered.

Discussion
This study provided the positive association between MyMathLab for Developmental Math mastery and performance on the final math exam as well as the aggregate of three quizzes. This association is between two independent variables after controlling for time spent on task in MyMathLab for Developmental Math and the average number of attempts in MyMathLab for Developmental Math.

A **caveat** of this study is that it did not account for other confounding factors in explaining the association between MyMathLab for Developmental Math mastery and academic performance after controlling for time on task in MyMathLab for Developmental Math and the average number of attempts in MyMathLab for Developmental Math.

In conclusion, this study does not allow us to make any causal statements. Instead, it only shows the relationship between MyMathLab for Developmental Math mastery and academic performance after controlling for time on task in MyMathLab for Developmental Math and the average number of attempts made in MyMathLab for Developmental Math.

Future Research Plans

Overview of Future Research Plans

Researchers at Pearson are conducting several quasi-experimental studies to assess the impact of MyMathLab for Developmental Math on the academic achievement and progression of students enrolled in community college. Pearson has commissioned researchers at the University of Michigan and the University of Texas at Dallas to complete secondary analysis of existing data that will allow them to compare the academic achievement and progression of students who used MyMathLab for Developmental Math with that of comparable students who did not use MyMathLab for Developmental Math. Another MyMathLab for Developmental Math study is a case-control study that will examine the use of MyMathLab in developmental courses at six institutions across the country.

Pearson researchers are also conducting an in-class pilot of Pearson's new adaptive homework capability for MyMathLab for Developmental Math to gather initial feedback from instructors and students regarding their experiences and satisfaction with the capability. Within this pilot, data scientists have embedded randomized A/B tests designed to assess the efficacy of Pearson's adaptive homework capability for MyMathLab for Developmental Math.

Future Research Plans

Quasi-experimental Study using Regression Discontinuity and Propensity Score Matching	
Intended Start Date	Spring 2016
Anticipated Length of Study	1 year
Type of Study	Quasi Experimental Design - regression discontinuity and propensity score matching
Research Leads	Stephen DesJardin (University of Michigan) and Rodney Andrews (University of Texas - Dallas)
Intended Sample Size	Over 1 million students enrolled in 33 community colleges from 2010-2015
Description of Sample	Samples will be drawn from the Pearson MyMathLab for Developmental Math platform and the State Longitudinal Education Data maintained at the Education Research Center at the University of Texas at Dallas, that contains information about the characteristics and academic achievement and progression of students enrolled at 33 community colleges in Texas.

Outcomes to be Measured	The outcomes to be assessed in this study include: 1. achievement in pre-college math and reading skills, 2. progression to the first credit-bearing math course, 3. progression to the first credit-bearing reading course, and 4. retention, and graduation from community college.

Proposed Study Description
The Pearson Efficacy, Research and Impact Evaluation team has commissioned faculty at the University of Michigan and the University of Texas to complete a quasi-experimental study using regression discontinuity and propensity score matching techniques to investigate differences in outcomes between students who were users of MyMathLab for Developmental Math (treatment group) and those that did not use MyMathLab for Developmental Math courses (comparison group). This study will rely on analyses of existing data from Pearson's MyMathLab for Developmental Math platform combined with State Longitudinal Education Data maintained Education Research Center at the University of Texas at Dallas, that is related to the educational trajectories of Texas students. More specifically, Pearson has accumulated a unique log of learning activity data from Texas students who have enrolled in developmental math programs since January 2007. In addition, community colleges in Texas also use Pearson's MyMathLab for Developmental Math for assessing and remediating college-and career-readiness skills in reading, writing and mathematics. Combining Pearson data about learning activities with the individual student-level higher education data housed in the University of Texas at Dallas' Education Research Center (UTD-ERC), along with additional information provided by community college districts, we intend to determine the effectiveness of MyMathLab for Developmental Math used in 33 Texas community colleges and will examine which components of the MyMathLab for Developmental Math may contribute to academic success and credential attainment.

Case-Control Study of MyMathLab for Developmental Math	
Intended Start Date	Q4, 2015
Anticipated Length of Study	2 years
Type of Study	Quasi Experimental Design - case-control
Research Leads	Pearson researchers and instructors at these institutions: 1. Robeson Community College, 2. Northwest Shoals Community College, 3. Oakton Community College, 4. Southcentral Kentucky Community Tech College, 5. Pulaski Tech, and 6. Coppin State University.
Intended Sample Size	1,985 students from 6 institutions
Description of Sample	This is a large sample with students from 6 institutions, which could be a good representation of students taking

	developmental math.
Outcomes to be Measured	The learner outcomes measured will be student access and perception of the learning experience, student final exam scores, final grades in the course, retention, course completion, progression to credit-bearing math course, and achievement in the first credit-bearing math course.

Proposed Study Description

Researchers in the Pearson Efficacy, Research and Impact Evaluation team are conducting a case-control quasi-experimental study in collaboration with the Pearson North America Customer Experience and Engagement team and instructors at six institutions where MyMathLab for Developmental Math is used. The goal of this study is to isolate the contribution of MyMathLab for Developmental Math to student success when all other factors that research has indicated are important predictors of student success are taken into account and are statistically controlled. Specifically, this two-year longitudinal study will take into account factors that impact students' academic achievement and progression and can differentiate students who succeed from those who fail to achieve and progress. Such factors include: students' prior academic experiences, their overall approach to academic work, out-of-school responsibilities, the type and intensity of academic advising students receive when they enroll in college, and the support they receive within their developmental courses.

In-Class Pilot and Embedded RCT for Adaptive Homework Capability in MyMathLab for Developmental Math	
Intended Start Date	Q1-Q2, 2016
Anticipated Length of Study	1 semester
Type of Study	Randomized Control Trial
Research Leads	Pearson researchers
Intended Sample Size	4 customer institutions
Description of Sample	4 institutions are targeted, representativeness depends on which institutions are recruited.
Outcomes to be Measured	Access, experience, achievement on specific assessments embedded within the courseware

Proposed Study Description

The goal of this in-class pilot is to gain insight into how the adaptive homework assignments are performing when used within a real classroom environment. In particular, the study will examine whether the system is performing as designed (functionality and quality), if the algorithm is performing as expected, and if instructors and students are satisfied with the adaptive homework experience. In this embedded experiment, all students in the courses will use

MyMathLab for Developmental Mathematics. However, for specific assignments, the technology is modified and students that have been randomly assigned to the treatment condition will complete their work using the adaptive homework capability (i.e. the feature is turned on). For the same assignments, students assigned to the control condition will use the unmodified MyMathLab for Developmental Math system (i.e. the feature is off). Data collected within MyMathLab for Developmental Math will be analyzed to identify differences in learning patterns and performance of students who used the adaptive homework capability against that of students who used the unmodified version of MyMathLab for Developmental Maths.

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