

# Online Developmental Mathematics: Challenging Coursework Traditions

By Taylor Martin, Scott Smith, Sarah Brasiel, and Ian Sorensen

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**ABSTRACT:** *Many students must take remedial or developmental mathematics coursework to gain skills and knowledge necessary to satisfy college-level quantitative literacy requirements; however, large numbers of those students struggle to complete such coursework and are consequently unable to graduate. This issue implies the need to reform developmental mathematics curricula, and modern developmental mathematics curriculum standards have been used as a basis reforming developmental mathematics curricula and programs at a number of community colleges and universities. We report an analysis of developmental mathematics assessment practices based on a large dataset, and how assessment practices indicate alignment with reform-oriented curriculum standards. We conclude with suggestions for improving developmental mathematics curricula.*

Several years ago President Obama announced his goal for America to have “the highest proportion of college graduates in the world” (Obama, 2009, para. 66). In order to meet this goal, the nation must address the problem of students graduating from high school underprepared for college-level mathematics. According to the annual report by the National Center for Education Statistics (NCES, 2014), nearly 33% of all current undergraduates have taken a remedial class of some sort, and during the 2011-2012 academic year (one of the years the data in our study comes from); 13% of all undergraduates took a remedial mathematics course. These numbers are higher for two-year institutions compared to four-year institutions and higher for African-American and Hispanic students compared to white students (NCES, 2014).

## The Setting for Developmental Mathematics Today

Curriculum programs designed to meet the needs of underprepared students for college mathematics are called either *remedial* (basic academic skills remediation) or *developmental* (integration of academic courses and support services) mathematics (Boylan, 1995; Voge, 2008). Many developmental education programs exist because there are gaps between high school graduation requirements and college or university entry requirements. Data from

the NCES indicate that as little as 27% of graduating high school seniors have taken the required coursework to prepare them for attending a college or university (Bettinger, Boatman, & Long, 2013). Because of gaps between what high school students are required to know at graduation and the preparation needed for postsecondary education, many students graduate from high school with inadequate knowledge and skills for college. Furthermore, adult learners who choose to attend college or university subsequent to spending time in the workforce after high school graduation often face the problem of having forgotten the mathematics content they learned in high school. The purpose of most developmental education courses is to remediate skill gaps to prepare students beginning postsecondary education, thus promoting academic success at the college or university level. One means by which developmental education programs at community colleges and universities accomplish this is by requiring and providing remedial coursework for students.

The developmental mathematics sequence differs by institution in the number of courses in the sequence (typically 2 or 3) and in the name of the courses in the sequence. However, the sequence usually begins with some sort of algebra readiness (prealgebra) course, followed by an elementary algebra course, and then an intermediate algebra course (Cullinane & Treisman, 2010). The beginning college-level mathematics course options also differ by institution but usually include precalculus, trigonometry, statistics, or other basic college mathematics courses for nonmathematics majors.

Community colleges teach the bulk of developmental mathematics courses; for each developmental mathematics course taught at a four-year institution, four are taught at community colleges (Mesa, Wladis, & Watkins, 2014). Ignash (1997) maintains that community colleges should be the primary provider of developmental mathematics courses because “community colleges are more accessible to students in terms of cost, location, and admissions policies” (p. 15) than four-year colleges. Community college students exhibit greater incidence of high-risk characteristics than students at four-year institutions, being more likely than students at four-year institutions to lack a

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high school diploma, to work full time, to have children, to be financially independent, and to be single parents and enrolled part-time (Goan, Cunningham, & National Center for Education Statistics, 2007). These high-risk characteristics contribute to the difficulties many community college students have completing required developmental mathematics coursework (Boatman & Long, 2010) and demonstrate the importance of developmental programs designed to address the obstacles these at-risk students face in pursuing postsecondary education.

However, policymakers perceive a number of problems regarding the effectiveness of developmental mathematics programs, with some questioning the necessity of these programs (Bahr, 2008). One problem is that students must learn in one course the same amount of content typically learned during an entire school year at the middle or high school level, resulting in high failure rates for developmental mathematics course sequences (Cullinane & Treisman, 2010). Another criticism of typical developmental mathematics coursework is that the increased time to degree completion imposed by additional coursework frequently results in student frustration. This is considered a reason why many students who take developmental coursework never complete their degree (Bailey, 2009; Cullinane & Treisman, 2010). Because of the high failure rates of developmental mathematics courses, Merseeth (2011) has described these courses as the graveyard of many students' dreams and aspirations.

Another perceived problem with traditionally implemented developmental mathematics courses is their orientation towards calculus preparation (Cullinane & Treisman, 2010). In the traditional algebra-to-calculus sequence of developmental courses, students learn numerous algebra topics they will never use in the workplace, such as factoring polynomials (Cullinane & Treisman, 2010). This sequence of coursework can lead many students to form the impression that STEM (science, technology, engineering, and mathematics) fields are unimaginative and dull, which may turn them away from pursuing careers in STEM areas (Olson, Riordan, & Executive Office of the President, 2012). This has been a motivating impetus for reforming developmental mathematics curriculum: to allow students to learn skills they believe are more relevant and lead to greater satisfaction with quantitative literacy requirements.

Statistics regarding the effectiveness of developmental mathematics programs indicate a number of troubling problems. Two out of three community college students who place into developmental mathematics coursework never actually complete the required preparatory and college-level coursework and consequently are unable to graduate (Cullinane & Treisman, 2010). Moreover,

Bailey (2009) reports that 20% of students placed into developmental mathematics coursework fail to enroll in a single course.

Because of the issues related to developmental mathematics coursework, many voices are opposed to developmental education. Some view developmental education programs as unnecessary roadblocks to students' completing their educational goals (CCA, 2012). Others believe that it is unfair to make taxpayers pay twice for students to learn content they should have learned in high school (Ignash, 1997). In particular, critics lament the cost of developmental mathematics programs, estimated at \$2.5 billion annually (Bailey, 2009). These concerns have influenced state legislation throughout the nation, and many states are setting up new policies for state funded postsecondary programs. For example, Florida recently has passed Senate Bill 1720, which makes developmental courses optional for students graduating from Florida high schools (Fain, 2013). Similarly, in 2012,

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Connecticut passed Public Act 12-40, which only allows one semester of developmental education courses for college students attending state schools (Fain, 2012). Finally, Texas plans to reduce the cost of developmental education by having less prepared students assigned to adult-basic education courses that are only offered at two-year colleges where tuition and costs are generally less (Mangan, 2014).

Proponents of remedial education argue that providing effective remedial education would go a long way towards alleviating many of the nation's social and economic problems (Astin, 1998). Others note that remedial education is one of the few programs in education that is a "lifeline to marginalized populations" (Bahr, 2010, p. 232). A recent NCES report makes this argument more poignant by showing that only 20% of white students take a remedial course compared to 30% of Black students and 29% of Hispanic students. Furthermore, empirical evidence suggests that students benefit from enrolling in developmental mathematics coursework. For example, studies have found that students who enroll in developmental mathematics in two-year and four-year colleges have a higher first-year retention rate than similar students who chose not to enroll in developmental mathematics course (Boatman, 2012; Lesik, 2007).

There have been many efforts in recent years to reform developmental mathematics curricula (Bonham & Boylan, 2011). Rutschow, Schneider, and MDRC (2011) identify four ways that post-secondary educators have attempted to improve developmental mathematics programs: accelerated coursework designed to decrease students' time to completion, supplemental programs such as advising and tutoring, interventions offered to students before entering postsecondary education, and programs in which students learn basic skills within the context of occupational or college-content coursework. These programs are examples of developmental education approaches rather than stand-alone remedial classes.

Additionally, in 1995 the American Mathematical Association of Two-Year Colleges (AMATYC) published the *Crossroads in Mathematics* curriculum standards intended for developmental mathematics programs (Cohen, 1995). The AMATYC Crossroads Standards make recommendations for the comprehensive reform of developmental mathematics programs, providing standards for intellectual development, content, pedagogy, and guidelines for achieving the standards. A number of developmental mathematics programs have successfully reformed their coursework based upon the recommendations of the AMATYC Crossroads Standards (Lucas & McCormick, 2007; Mireles, 2010; Waycaster, 2001). In particular, the AMATYC Crossroads Standards for content recommend that developmental mathematics courses should contain content specific to number sense, symbolism and algebra, geometry, function, discrete mathematics, probability and statistics, and deductive proof.

The particular content assessed in mathematics courses using online textbooks provides indications of the content emphasis of developmental mathematics coursework. We conducted our study to investigate the alignment between the content of developmental mathematics courses as indicated by assessment practices within the online curricula and the AMATYC Crossroads Standards for content. Hence, we designed our study to answer the following research question: What is the degree of alignment between the AMATYC Crossroads Standards and assessment practices based on data collected by an online developmental mathematics curriculum provider?

## Method

An educational textbook company that is one of the largest publishers of online course materials and course management software for colleges and universities to support mathematics instruction provided the data used for this study. The dataset was randomly selected by the company from a set of courses during the 2011-2012 and the 2012-2013 school years, and included the use

of five online developmental mathematics textbooks over a 2-year period. The data set included 46,139 students in 1,836 courses at 976 two-year and four-year institutions. Student and instructor demographics were not available. Data were collected during normal use of the online course management system. We do not know if the students were enrolled in online courses, face-to-face courses or some combination of the two. An instructor could provide classroom instruction face-to-face and then assign classwork, homework, and assessments using the online textbook and online course management system.

The dataset included all types of assignments students were given and how many they completed (including homework, quizzes, and tests). However, tests are the clearest indicator of unique item assignment and completion because students could often retake quizzes and re-do homework assignments within the online system. Therefore, we reduced our analytics sample to the exam items on chapter tests. The five textbooks included in the data set were: (a) pre-algebra, (b) basic college mathematics, (c) developmental mathematics, (d) beginning algebra, and (e) intermediate algebra.

### Data Analyses

We conducted an exploratory investigation of the textbook content used by instructors in developmental mathematics courses to prepare students for future mathematics courses. To do this we first calculated the number of items included on exams for each chapter. We did this calculation of exam items for each chapter for each of the five textbooks in the dataset. Next, we looked at the chapter titles to create a list of common mathematics content areas related to the chapter titles. The wording of many of the chapter titles was identical; however, some combined two areas into one chapter versus separate

chapters (e.g., addition and subtraction of fractions in one chapter and multiplication and division of fractions in another chapter). The authors, two of whom are postsecondary mathematics faculty, reviewed the content of the textbooks and found

that there were 20 key mathematics content areas identified within the chapters.

Once we had the sum of exam items by each identified topic area, we calculated the sum of the exam items to obtain a grand total of exam items for

**Table 1**

### *Distribution of Exam Items by Topic and Textbook*

Topic	Pre-Algebra		Basic College Math		Beginning Algebra		Intermediate Algebra		Developmental Math	
	Total Items	% of Course Test Items	Total Items	% of Course Test Items	Total Items	% of Course Test Items	Total Items	% of Course Test Items	Total Items	% of Course Test Items
Whole Numbers	245488	20%	359031	19%					64946	4%
Fractions	188959	15%	436585	23%					150134	10%
Decimals	102038	8%	179178	9%					44824	3%
Ratio and Proportion	87500	7%	115831	6%						
Percent	78661	6%	188799	10%					100851	7%
Geometry and Measurement	120994	10%	160252	8%					26668	2%
Graphing, Statistics, and Probability	67942	5%	62957	3%	102525	13%			26377	2%
Integers and Solving Equations	309855	25%	423954	22%						
Real Numbers					122686	15%	57465	4%	236134	16%
Solving Equations and Inequalities					152679	19%	226926	17%	195251	13%
Graphs of Equation and Inequalities							159414	12%	149331	10%
Systems of Equations and Inequalities					56430	7%	62129	5%	28269	2%
Exponents and Polynomials	46105	4%			160859	20%	290652	22%	154613	10%
Factoring Polynomials					120765	15%			169993	11%
Quadratic Equations					9362	1%	66511	5%	50923	3%
Rational Expressions					37539	5%	143855	11%	74194	5%
Roots, Radicals, and Complex Numbers					40660	5%	263781	20%	46262	3%
Exponential and Logarithmic Functions							41239	3%		
Conic Sections							7932	1%		
Sequences, Series, Binomial Theorem							5642	0%		
Grand Total Items	1247542		1926587		803505		1325546		1518770	

the courses using each book. For each topic area, we determined the percent of the course content that was focused on that area by dividing the number of items for that topic area by the total number of exam items and then creating a percentage. Finally, we looked across the percentages to identify the two highest percentages to represent the two main topic areas for each book with the largest number of items tested on exams as a proxy for what possibly could be the two areas of greatest focus for the course. We also looked for any other interesting patterns in the course content coverage.

## Results

When comparing the five books we found a very different distribution of content covered in each book (see Table 1). The lower level basic concepts from whole numbers to beginning algebra with solving basic equations were the main concepts covered in the pre-algebra and the basic college mathematics textbooks. The beginning algebra and intermediate algebra textbooks seemed to pick up where these two left off, with intermediate algebra increasing the scope of algebra topics covered. The developmental mathematics textbook spanned the lower and the higher content area topics.

Next, we looked at the percent of total items covered across topics to identify the two topics with the greatest percent of total items tested for each textbook. First, we found that for the pre-algebra textbook, the topics of “whole numbers” and “integers and solving equations” were highest (20% and 25% respectively). Second, for the basic mathematics textbook, we found that “fractions” and “integers and solving equations” were the most tested topics (23% and 22% respectively). Third, for the beginning algebra textbook the two topics tested the most were “solving equations and inequalities” and “exponents and polynomials” (19% and 20% respectively). The intermediate algebra textbook had “exponents and polynomials” and “roots, radicals, and complex numbers” as the two most tested topics (22% and 20% respectively). Finally, the developmental mathematics textbook, which covered the largest number of topics, had the topics of “real numbers” and “solving equations and inequalities” as the two most tested (16% and 13% respectively).

## Discussion

Our analysis of the assessment practices suggested that the courses emphasized three of the AMATYC Crossroads Standards: number sense, symbolism and algebra, and function. Furthermore, the analysis of the assessment practices revealed little or no emphasis for these courses on the other standards including geometry, discrete mathematics, probability and statistics, and deductive proof. The course titles, the contents of the online course materials, and our analysis of the

data of assessment practices indicate that these courses heavily emphasize algebra learning. This emphasis on algebra content suggests the courses are intended to prepare students for taking calculus courses, regardless of individuals’ course of study or whether the students subsequently enroll in calculus courses.

## Limitations

There are a number of limitations to this study. One limitation is that a single publisher provided the data we analyzed in this study, which presents a possible bias in the outcomes. However, the assessment data we analyzed were randomly selected from a much larger population of students enrolled in developmental mathematics courses. A second limitation of the study is the lack of information on the setting, type of university, or student demographics in the data set. It is possible that data were collected from institutions of higher education that are not consonant with the overall population of colleges and universities in the U.S. A third

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### *These courses heavily emphasize algebra learning.*

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limitation of the study is that we used assessments to make inferences about the content of developmental mathematics coursework, which does not necessarily reflect the actual content that students learn from the coursework. Any difference or disparity between assessment practices and actual course content warrants further investigation.

## Implications for Practice

The assessment practices we found indicate a low level of alignment of the sampled developmental mathematics courses with the AMATYC Crossroads Standards, and many topics emphasized by the Standards were not assessed, including geometry, probability and statistics, discrete mathematics, and deductive proof. Considering the low level of success of students placed into developmental mathematics courses and the significant problem this poses, we recommend that mathematics departments heed the guidance of the AMATYC Crossroads Standards for reforming developmental mathematics. Empirical evidence demonstrates the effectiveness of reform efforts based on these standards (Lucas & McCormick, 2007; Mireles, 2010; Waycaster, 2001). In addition, practitioners may wish to check the alignment between assessments and the curriculum. Questions should match all concepts covered and be parallel in number to the percentage of time spent.

Two questions that need to be answered are: Do all developmental students need the same degree of

mathematics? Should industry play a greater role in informing what level of mathematics is needed for the jobs in high demand? Many organizations are asking questions of this kind, and there is growing pressure for greater alignment between the needs of private industry and the government sector and the content taught in developmental mathematics courses. Numerous businesses and organizations believe that students are emerging from college and university mathematically unprepared to enter the workforce. Indeed, a report issued by the U.S. Department of Education calls for the need for developmental education programs to redesign their curricula with greater consideration for the needs of private industry and the military (Golfin, Jordan, Hull, & Ruffin, 2005).

## Future Research

The limitations of our study suggest the need for additional research using methodologies that allow for a better understanding of the demographics of students using online developmental mathematics curricula as well as the specific characteristics of institutions of higher learning offering courses using these online resources. In particular, there is a need for further investigation of developmental mathematics assessment practices from a larger population of developmental mathematics students. A comparison of outcomes from students who take such coursework in traditional face-to-face settings and those using online resources is also in order. Additionally, subsequent research could clarify the relationship between the content of developmental mathematics courses and the AMATYC Crossroads Standards.

## Conclusion

The main findings from this study of five developmental mathematics online textbooks indicate that they present mathematics via a traditional curriculum: primarily emphasizing calculus-oriented content such as algebra. We recommend that mathematics departments revise their developmental mathematics coursework to take into consideration both the guidance of the AMATYC Crossroads Standards as well as the occupational needs of industry and the labor market. In particular, the AMATYC Crossroads Standards is an important policy document intended to guide the reform of developmental mathematics coursework and potentially allow more students to successfully pass their developmental course or sequence, enhance student success, better meet industry needs, contribute to their positive experiences in higher education, and meet industry needs. As more developmental mathematics courses move to online delivery and the focus of postsecondary mathematics is shifting, we recommend the use of this type of content analysis, or similar content analysis, for any online course offered at

institutions of higher education or other educational settings. Such studies can assist educators to better understand curriculum development, teacher assessment practices, and appropriate content coverage given the standards or expectations for a particular course. With student success as the goal, analysis and evaluation of developmental mathematics is essential to turn the tide toward degree completion.

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