Computer Based Mastery Learning in Developmental Mathematics Classrooms

By Annie Burns Childers and Lianfang Lu

The Pre-Core program... consisted of 10 modules of content and was based on mastery learning of each module.

Annie Burns Childers
Assistant Professor
abchilders@ualr.edu

Lianfang Lu
Associate Professor

Department of Mathematics and Statistics
University of Arkansas at Little Rock
2801 South University
Little Rock, AR 72204

ABSTRACT: Failures of developmental mathematics education are no secret. As a response to improve the success of students enrolled in these courses, different redesign efforts have been implemented across the country. This study reports on one redesign effort that began in Fall 2012. The new design consisted of mastery learning in computer-based developmental mathematics classrooms. Data from the design were gathered and statistically analyzed with regard to completion rates, length of completion time in the program, success in college-level mathematics courses upon program completion, and contributing factors to students' success in the program. Findings indicate that this type of redesign may not lead to dramatic results in student success and outcomes of these courses. Further research is needed to continue to find ways to better serve this population of students.

The failures of remedial courses, sometimes referred to by researchers as developmental education, are well known (Clery, 2006; Vandal, 2014). According to Vandal (2014), research indicates that around 50% of all new entering postsecondary education students place into remedial classes. Out of the students who place into remedial courses, for mathematics in particular, students experience high rates of failure (Bonham & Boylan, 2011). According to Mitchell (2014), only one in four will earn a degree or certificate. As a result of low graduation rates for students who initially start in some form of remediation, critics argue that these students should not attend college. They claim these students have no chance of being college successful if they are performing mathematics and reading at a middle school level. Others argue that it is necessary to provide equal opportunity to all students, especially since many students in remediation come from disadvantaged backgrounds (Mitchell, 2014).

The barrier of mathematics remediation to college success caught national attention when President Obama's administration gave $10 million to a partnership of Columbia University, the Community College Research Center, and the research group MDRC to fund a research center targeted at an overhaul of mathematics remediation (Mitchell, 2014). Even more recently, 22 states signed a commitment to the White House to increase gateway course completion in one academic year for remediation students (The Executive Office of the President, 2014).

As demands for higherlevel skills continue to increase, postsecondary education has become more of a necessity for high school graduates (Lucas & McCormick, 2007). As a result, an increasing number of high school graduates are entering community colleges and four-year institutions. Many of them are underprepared (Camera, 2016), causing a problem of remediation that will only persist (Rich, 2015).

Over the last decade, the attention that has been given to the low success rates in remediation classes has brought about different redesign efforts (Bonham & Boylan, 2011; Knepler, Klasik, & Sunderman, 2014; Lucas & McCormick, 2007; Mangan, 2014; Vandal, 2014; Weissman et al., 2011). As schools move away from a traditional model of developmental mathematics, which may include two or three classes a student must pass in order to reach the college-credit mathematics course, designs such as mastery learning, active learning, modularized, personalized assistance, individualized assistance, corequisite, and multiple pathways have emerged (Bonham & Boylan, 2011) as strategies to improve student success.

In an effort to align with the redesign of mathematics remediation and in an attempt to increase retention and pass rates in these classes, in Fall 2012 a modularized computer-based model was implemented at a four-year public university in the south central United States. Previous to this, the university offered the traditional 2-semester course sequence: Beginning Algebra for those who were deemed very deficient in mathematical skills and Intermediate Algebra for those were deemed deficient but not as low as those who placed into Beginning Algebra.

The new design, titled the Pre-Core program, was developed by mathematics and statistics faculty at the university. It consisted of 10 modules of content and was based on mastery learning of each module. Mastery Learning is described as a learning system in which one set of content and learning objectives must be learned before moving on to the next set of skills. Classes met in a computer lab twice a week for 50 minutes. During this time, students worked on the mathematics online software ALEKS. Tutors walked around the room checking on students and assisting them when needed.

When a student completed all the topics in a particular module, they then took a proctored assessment in ALEKS over the content. The proctored assessments were required to be taken on campus in the computer lab. There were specific time slots allowed for testing. For this program, mastery of modules was determined by obtaining a score of 80% or higher on a proctored assessment for each module. Once a student mastered a module, they then moved on to the next one. Once a student mastered eight modules, they were eligible to exit the Pre-Core program to the course Quantitative and Math Reasoning (a college-level mathematics course that satisfies the mathematics degree requirement for non-STEM majors). Once a student mastered 10 modules, they were eligible to exit the Pre-Core program to the course College Algebra. This path is illustrated in Figure 1.

In an attempt to allow students to proceed at their own pace to earn mastery of content for each module, four courses named "Pre-Core" were developed. All students needing mathematics remediation started in Pre-Core I; however, if they did not finish all 8 or 10 modules required in 1 semester, they then continued to Pre-Core II for a second semester and so forth until, ultimately, Pre-Core IV if needed. Whichever Pre-Core class the student was in, whenever they finished the required 8 or 10 modules (depending on their major), they were finished with mathematics remediation. The idea of the redesign was that students could work at their own pace, accelerate the time spent in developmental mathematics classrooms, have tutors on hand to ask questions to in class, and ensure mastery of topics before moving on to new content.

The purpose of this study was to research the student success and outcomes of the Pre-Core program, which used the mastery approach in a computer-based learning environment in developmental mathematics classrooms. By outcomes we mean specifically the following subquestions:

1. How many students successfully completed the Pre-Core program (8 or 10 modules) in 2 academic years?
2. How long did it take students to complete the Pre-Core program?
3. How successful were students in their college-level mathematics course after completion of the Pre-Core program?
4. Did length of time spent in the Pre-Core program make a difference on performance in their college-level mathematics course?
5. For those who completed the Pre-Core program, were there any factors that contributed to their success?

Those who were in the control group and not enrolled in a learning community caught up after the program participation ended.

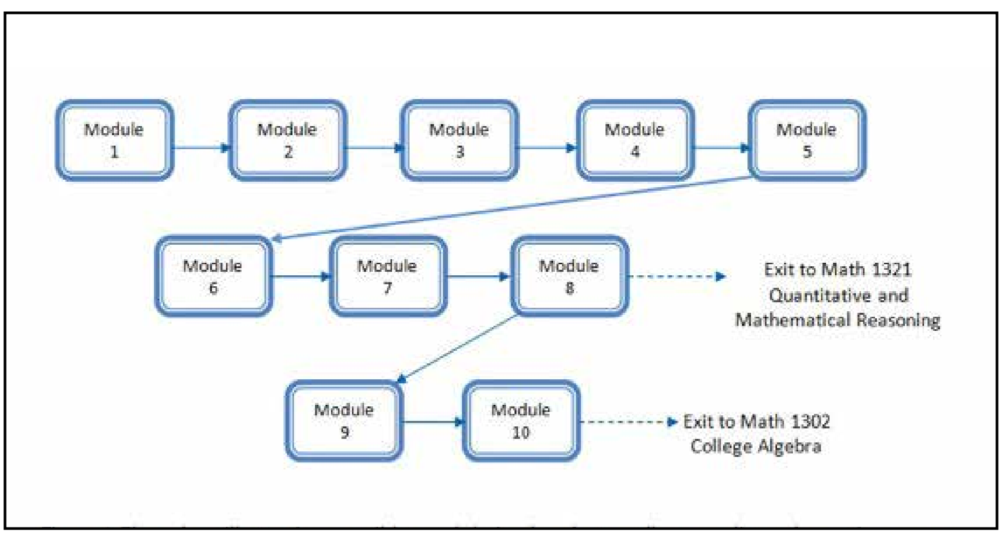

***Figure 1*. Flow chart illustrating possible modularized paths to college credit mathematics courses.**

Literature Review

There are many reasons which possibly contribute to low pass rates in mathematics remediation classes. Anxiety, long sequences of classes, lack of study skills, and the idea that it is socially acceptable to fail mathematics all can be contributing factors (Boylan, 2011). For nontraditional students, many have jobs and families which influence time management and priorities. As a result of low pass rates, research on different mathematics remediation approaches is consistently emerging. National Center for Postsecondary Research (NCPR) conducted a study which found that students enrolled in a learning community, a model that enrolls a cohort of students in two classes together (Weismann et al., 2011), were more successful in their developmental mathematics course. However, persistence did not continue as those who were in the control group and not enrolled in a learning community caught up after the program participation ended (Weismann et al., 2011). Woodard and Burkett (2005) compared the success rates of developmental mathematics students enrolled in a 5-hour credit course versus a 3-hour credit course that included the implementation of an exit exam. They found that students enrolled in a 3-hour credit course were just as successful as those enrolled in a 5-hour credit course. For the 5-hour credit courses, they also found that there were more unsuccessful grades after the implementation of an exit exam, possibly a result of higher expectations. On the other hand, for the motivated student, findings have shown that an accelerated approach (self-paced, corequisite, blended courses) could help accelerate student completion and transition into credit-bearing mathematics courses (Booth et al., 2014).

Not only have mathematics faculty attempted to increase mathematics remediation success rates, but policy makers at these institutions have also attempted to implement policies towards this effort. Mangan (2014) found that strict attendance policies were beneficial as students were nearly three times as likely to complete the course when one was in place. Findings also indicated that students who registered for college-level courses before the term began were eleven times more likely to persist into their second year (Mangan, 2014). Another policy mandating student enrollment in mathematics remediation courses during the first semester of college has also proven effective. Students to whom this restriction was applied achieved the same outcomes (First Semester GPA, Fall-to-Spring retention, Fall-to-Fall retention) as the college ready students (Fike & Fike, 2012). Booth et al. (2014) reported policy changes to particular institutions in Texas such as early registration deadlines 10 days before classes to maximize student enrollment and mandatory student orientation. Both resulted in an increase of success, measured by pass rates, in developmental mathematics students.

As redesign efforts in developmental mathematics programs have increased, the role of technology and computers in these programs has been emerging (Epper & Baker, 2009). The idea of using computers in mathematics classrooms became popular with the development of what has been labeled the emporium model. Originated at Virginia Tech, key components of this model are "interactive computer software, personalized on-demand assistance, and mandatory student participation" (Twigg, 2011, p. 26). The emporium model, which typically yields a low cost factor, has shown to be effective at several large institutions, including institutions that offer mathematics remediation courses. In addition, Allegany College of Maryland found that students who used an e-Learning platform in a mastery based developmental mathematics classroom had a higher success rate than those who did not (Boggs, Shore, & Shore, 2004). In fact, they found that those who used the e-Learning platform had a success rate of 66% (N=40) compared to a success rate of 55% (N=220) for those who did not. Foothill College's Math My Way program employed an intensive design of rigor and time on task by using ALEKS mathematics software in a self-paced classroom environment. Preliminary outcomes suggested a 20% higher success rate than for those who were enrolled in the traditional program (Epper & Baker, 2009).

Many agree that the use of technology is important in developmental mathematics classroom; however, when Spradlin and Ackerman (2010) did a study on the effectiveness of using computers to assist instruction in developmental mathematics classes, they found no difference in the computer assisted instruction versus the traditional lecture. They suggest that "the mere presence of computers does not improve student learning" (p. 14). More recently, Ariovich and Walker (2014) found that students in modular computer-based classes seemed to perform comparatively worse than students in a traditional classroom. They found difficulties by instructors to connect with students, gaps in explanations of computer software, and challenges for students developing time management strategies all possible contributing factors to the low pass rate.

As a response to low success rates for students enrolled in developmental mathematics classes, many institutions and policy makers are continuing to redesign and look at ways to increase student success and pass rates in these classes. Some institutions appear to have effectively used technology to increase success in developmental mathematics programs (Epper & Baker, 2009); however, addressing challenges requires careful assessment of redesign efforts (Ariovich & Walker, 2014). In general, since research on developmental coursework and success rate is limited (Barnett, 2008; Esch, 2009), the focus of this study is to research the student success and outcomes of the Pre-Core program, which used the mastery approach in a computer-based learning environment in developmental mathematics classrooms at a four-year public institution

Methodology

This study analyzes data starting in Fall 2012 of first time entering freshman students enrolled in mathematics remediation at a four-year public university. Located in the south central United States, this institution has an undergraduate population of about 9,000 students. Approximately 59% are female, and 41% male. About half are Caucasian, one-fourth African American, one-twelfth Hispanic, and one-sixth fall into other categories such as Asian, American Indian, or more than one

Table 1
Demographics by Cohorts

Demographics	Fall 2012 (n = 352)	Spring 2013 (n = 60)	Fall 2013 (n = 278)	Spring 2014 (n = 63)	All (N = 753)
Gender					
Male	147	21	120	19	307
Female	205	39	158	44	446
Race					
Caucasian	141	26	97	33	297
African-American	128	16	126	19	289
Two or more Races	46	9	31	4	90
Hispanic	10	5	8	4	27
Asian or Pacific Islander	9	1	5	2	17
American Indian/Alaskan Native	1	0	3	0	4
Unknown	17	3	8	1	29
Age range					
Under 20	0	0	0	1	1
20-29	315	48	232	51	646
30-39	19	8	32	6	65
40-49	13	3	8	4	28
50 and older	5	1	6	1	13
Enroll status					
First-time entering undergraduate	279	17	185	29	510
First-time entering undergraduate transfer	50	17	65	19	151
Other first-year continuing student	14	24	22	13	73
Readmitted undergraduate	9	2	6	2	19

race. About half of the students are enrolled part-time, and half are enrolled full-time. Out of those enrolled full-time, around 94% are on financial aid.

Profile of Participants

A total of 753 students met the selection criteria. Among them, 352 beginning in Fall 2012, 60 in Spring 2013, 278 in Fall 2013, and 63 in Spring 2014. Spring semesters had the lowest number of students due to the fact that most entering freshman students started in fall semesters. Gender specific, the sample had more females (446, 59.2%) than males (307, 40.7%), representative of the university population. Racially, the sample included slightly more Caucasians (297, 39.4%) than African Americans (289, 38.4%). It also included about 3.6%, or 27 Hispanic, and 12%, or 90 two or more races. Compared to the university population, more African Americans were enrolled in developmental mathematics than Caucasians. The age ranged from 18 to 77 with an average age of 24.52, median 22, and $SD = 6.783$. The majority of the sample were first-time entering undergraduates (510, 67.7%). About 151, or 20% were first-time entering undergraduate transfers, 73, or 9.7% were other first-year continuing students, and 19, or 2.52% were readmitted undergraduate students (see Table 1 for more information of demographic information by cohorts). Academic background was measured by ACTMath and SATMath scores. The sample overall had a mean score of 17.10 ($N = 523$, $SD = 1.63$) on the ACTMath and a mean score of 430.77 ($N = 26$, $SD = 37.41$) on the SATMath.

Procedure

At this university, Fall 2012 was the first semester that the computer-based mastery redesign for mathematics remediation began. Institutions often have different cut scores for placement into classes, and some four-year institutions do not offer lower level classes; they may, instead, send students to the community colleges to take care of these requirements. For the institution in this study, placement into mathematics remediation was based on a student scoring lower than a 21 on the ACTMath, lower than a 500 on the SATMath, or lower than a 45 on the COMPASS Algebra. Every student whose test scores were under these thresholds started in Pre-Core I, in Module 1, regardless of any previous developmental courses (unless he or she had passed Intermediate Algebra, or an equivalent with a C or greater; in this case the student was eligible to enroll in college-level mathematics).

Data Collection

Data were collected from the Office of Institutional Research. The sample was selected based on meeting all three of the following criteria: (a) first time entering freshman during Fall 2012 through Spring 2014, (b) score of less than 21 on the ACTMath or less than 500 on the SATMath, and (c) enrolled in at least one Pre-Core mathematics class. We then sorted the students into four cohorts based on their first semester of study: Fall 2012, Spring 2013, Fall 2013, and Spring 2014. We studied each cohort over 2 academic years (including summer) in order to track each student throughout the Pre-Core program to analyze length of time in the program, program completion, and grade in college-level mathematics course if the Pre-Core program was completed.

The data were quantitatively analyzed by using the statistical software package SPSS. Descriptive statistics such as frequencies, percentage, mean, and standard deviation were computed to describe the central tendency and variation. Inferential statistics such as one-way ANOVA test with Post hoc and Chi-Square tests were conducted for comparison of the differences between subgroups within the sample. One-way ANOVA analysis was run for continuous variables, and the Chi-Square test was done for categorical variables. An alpha level of $p < 0.05$ was established for all statistical procedures in this study.

Table 2
Demographics of Completers versus Incompleters

Demographics	Completers (*n*=251)	Incompleters (*n*=502)	All (*N* = 753)
Gender			
Male	95	212	307
Female	156	290	446
Race*			
Caucasian	119	178	297
African-American	70	219	289
Two or more Races	32	58	90
Hispanic	8	19	27
Asian or Pacific Islander	8	9	17
American Indian/Alaskan Native	2	2	4
Unknown	12	17	29
Age range			
Under 20	0	1	1
20-29	209	437	646
30-39	26	39	65
40-49	14	14	28
50 and older	2	11	13
Enroll status			
First-time entering undergraduate	178	332	510
First-time entering undergraduate transfer	38	113	151
Other first-year continuing student	27	46	73
Readmitted undergraduate	8	11	19

Note: * The category has statistically significant differences between completers and incompleters.

Results

Completion Rate of Pre-Core Program

From Fall 2012 to Spring 2014, among the 753 students, 251, or 33.3% completed the Pre-Core program. Completion was defined if the student earned a grade of AQ (completion of 8 modules) and could exit to take the college-level course Quantitative and Mathematical Reasoning (QMR) for non-STEM majors, or earned a grade of AA (completion of 10 modules) and could exit to take the college-level course College Algebra. Throughout the manuscript, we will refer to the students who earned the AQ or AA grade as "completers," meaning that they completed the Pre-Core program, and at that point were eligible to enroll in a college-level mathematics course.

Spring 2013 student cohort had the largest percentage of completers (38.3%), followed by Fall 2012 (36.1%), Spring 2014 (34.9%) and Fall 2013 (28.4%). The results from the Chi-Square test indicated there was no significant difference in the completion rate between the four cohorts included in the study from Fall 2012 to Spring 2014 cohorts ($x2$ (3,753) = 4.964, p = 0.174). Table 2 shows the demographic information of students who completed the Pre-Core program (completers) and students who did not complete (incompleters). The results from the Chi-Square tests ($x2$ (6,753) = 20.01, p = 0.003) also showed there was a significant difference in race as the completion rate of Caucasians had the largest percentage of completers (47.4%) over incompleters (35.4%). Overall, Caucasian and Asian-Pacific students had higher rates of completion in the Pre-Core program than the other racial ethnicities.

Furthermore, we examined ACTMath scores between completers and incompleters of the Pre-Core program. A one-way between subjects ANOVA was performed to compare the effect of ACTMath scores on completions of Pre-Core. The results indicate that the completers (N = 167, M = 17.56, SD = 1.48) had significant higher mean scores on ACTMath than incompleters (N = 356, M = 16.89, SD = 1.65) at the level $p < 0.05$ for the completers and incompleters [F (8, 514) = 3.12, p = 0.02].

Length of Time in Pre-Core Program versus Performance in College-Level Mathematics Class

The completers (N = 251) varied in length of time to complete the Pre-Core program. Results indicated that 90, or 35.9%, completed Pre-Core in 1 semester, 133, or 53%, completed in 2 semesters, and 28, or 11.2%, in 3 semesters. No one completed the Pre-Core program in 4 semesters. On average, students spent about 1.8 semesters to complete the Pre-Core program.

For the 251 students who completed the Pre-Core program, 101 passed College Algebra and 45 passed QMR. Thus, 146, or about 58.1% of the 251 completers went on to pass a college-level mathematics course. The remaining 105 completers either did not enroll in the college-level math or did not pass. The mean score for College Algebra (M = 2.87, SD = 0.88) was slightly higher than that for QMR (M = 2.47, SD = 1.04) at the grade scale of A = 4, B = 3, C = 2, and D = 1. Results indicated that students who passed college-level mathematics class(es) were primarily 1- or 2-semester completers of Pre-Core (about 98%). Very few 3-semester completers passed College Algebra or QMR.

To further analyze length of time in the Pre-Core program to completers' performance in college-level mathematics classes, a one-way between subjects ANOVA was conducted. The results showed that the students who completed Pre-Core in 1 semester had the highest mean score in College Algebra (N = 55, M = 2.96, SD = 0.902), with 2-semester completers next (N = 43, M = 2.81, SD = 0.824), and 3-semester completers last (N =3, M = 2.0, SD = 1.0). However, there was not a significant effect of the length of completion on students' performance at $p < 0.05$ level for the three groups [F (2, 98) = 0.016, p= 0.984]. Students' performance in QMR had a similar pattern: 1-semester completers (N = 10, M = 2.80, SD = 1.135) had the highest mean score, followed by 2-semester completers (N = 33, M = 2.42, SD = 1.001), and 3-semester completers (N = 2, M = 1.50, SD = 0.707). The one-way ANOVA analysis showed there was not a significant effect of different length of time to completion on the performance of completers at the level $p < 0.05$ in the three groups in QMR [F (2, 42) = 1.015, p = 0.371].

ACTMath scores have an effect on the length of completion of the Pre-Core program.

Factors of Students' Success in the Pre-Core Program

To further understand the factors of students' success in the Pre-Core program, a one-way between subjects ANOVA was conducted to compare the effect of ACTMath scores on length of completion in 1-semester completers (Group 1), 2-semester completers (Group 2), and 3-semester completers (Group 3). The one-way ANOVA analysis results indicated there was a significant effect of ACTMath scores on the length of completion at the level $p < 0.05$ for the three groups [F (2, 164) = 6.979, p = 0.001]. Post hoc comparsions using the Tukey HSD test indicated that the mean score for Group 1 (M = 18.07, SD = 1.54) was significantly different than Group 2 (M = 17.43, SD = 1.388) and Group 3 (M = 16.83, SD = 1.32). However, there was not a significant difference of ACTMath scores between Group 2 and Group 3. Taken together, these results suggest that ACTMath scores have an effect on the length of completion of the Pre-Core program. Those students who had higher ACTMath scores tended to complete the Pre-Core program in 1 semester. It should be noted that 2-semester and 3-semester completers do not appear to have significantly different ACTMath scores.

Chi-Square tests were performed to test if there were any significant differences among the three groups of completers in relation to their demographics. The results indicated there was no significant differences with respect to race ($x2$ (12, 251) = 16.133, p = 0.185), gender ($x2$ (2, 251) = 0.289, p = 0.866), enroll status ($x2$ (6, 251) = 7.440, p = 0.282) or age group ($x2$ (6, 251) = 4.43, p = 0.624).

In summary, this study included a total of 753 students who enrolled in the developmental mathematics Pre-Core program as freshman during Fall 2012 to Spring 2014. We found 251 out of 753, or 33.3% of students completed the Pre-Core mathematics program with either a grade of AQ (exit to Quantitative and Mathematical Reasoning) or AA (exit to College Algebra). The majority of the completers were first time entering undergraduates (70.92%). Caucasian had the largest percentage of completers (47.4%). Gender wise, there were more female (62.15%) than male (37.84%) completers. The study shows about 89% (223 out of 251) completed in 1 or 2 semesters, and only 11% in 3 semesters. We also found that the pass rate of college mathematics courses for completers of the Pre-Core program was 56% for College Algebra and 60% for QMR respectively. The mean grade for College Algebra was 2.87 (SD = 0.88), about C+, and 2.47 (SD = 1.04), about C-, for QMR. Specifically looking at those who passed college-level mathematics courses, about 98% were 1- or 2-semester completers, 2% were 3-semester completers, and there were no 4-semester completers. However, there were no statistically significant differences in the mean score of grades in either College Algebra or QMR among 1-semester, 2-semester, or 3-semester completers.

The study also indicated that the completers had significantly higher mean scores (M = 17.56, SD = 1.479) on ACTMath than incompleters (M = 16.89, SD = 1.647). Moreover, there were significant differences in ACTMath mean scores between 1-semester and 2-semester completers and between 1-semester and 3-semester completers. The result implies that students who had higher ACTMath tended to complete the Pre-Core program in a shorter amount of time. In addition, we found that, statistically, Caucasian and Asian-Pacific

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students had significantly higher rates of completion of the Pre-Core program than the other racial ethnicities. Caucasians had the highest percentage of completers. However, there was no significant difference among 1-semester, 2-semester, and 3-semester completers with respect to race, gender, enroll status, and age.

Discussion and Implications

This study suggests several findings. First, contrary to Booth et al. (2014) and Epper and Baker (2009), we found that the computer-based mastery approach used in the Pre-Core program did not reduce the amount of time students spent in developmental mathematics classes. Most students still spent an average of 2 semesters to complete mathematics remediation, the same amount of time that was spent in the traditional model of Elementary Algebra and Intermediate Algebra. When redesigning developmental mathematics curriculum, if acceleration is a goal, mastery based in a computer environment that allows students to work at their own pace over a duration of up to 3 or 4 semesters may not be effective, particularly under the Pre-Core program setting.

Second, a pass rate of 33.3% for the Pre-Core program suggests that it is not as highly effective when compared to pass rates of other types of programs. Other programs, such as Austin Peay State University in Tennessee, saw pass rates for their developmental students increase from 23% to 54% in an elementary statistics class and 33% to 71% in a foundational mathematics class by implementing a corequisite design (Complete College America, 2013). Boggs et al. (2004) reported a 66% success rate when using an e-learning software platform in the classroom versus a 55% success rate in classes without. At Jackson State Community College, students earning a grade of C or better in their developmental classes increased from 41% in the traditional course to 54% in the redesigned accelerated format, which combined three developmental mathematics classes into one (Epper & Baker, 2009). The fact that our redesign effort resulted in only a 33.3% pass rate indicates that using computer-based mastery learning in developmental mathematics classrooms may not be effective at moving students through the pipeline to their college-level mathematics course, particularly under the studied program setting, participants, and software.

Third, the length of time with respect to 1 or 2 semesters spent to complete the Pre-Core program did not have a significant effect on how the student then performed in the college-level mathematics course. Those who finished the program in 1 or 2 semesters performed about the same in their college-level mathematics course. Those, however, who took longer than 2 semesters to finish the Pre-Core program were less likely to pass their college-level mathematics course. Per these results, it is suggested to design a program that forces students to spend at a maximum, 2 semesters in mathematics remediation.

Out of those who successfully completed the Pre-Core program, about 58% then passed their college-level mathematics course. This indicates that about 42% of Pre-Core program completers were lost in the pipeline towards obtaining a college-level degree. Those who were most successful at completing the Pre-Core program were first-time entering undergraduate Caucasian females. As literature suggests that students who are a racial minority are less likely to be successful in developmental mathematics (Mitchell, 2014), this finding does not come as a surprise. Efforts should be made to engage minorities to make sure they are successful in their follow-up college credit mathematics course. In order to understand more about the factors that contribute negatively or positively to the Pre-Core program, a further study is needed on relationships between students' attendance and family support with respect to their performance in the Pre-Core program.

We found that the computer-based mastery approach used in the Pre-Core program did not reduce the amount of time students spent in developmental mathematics classes.

Lastly, students with a higher ACTMath score tended to finish the Pre-Core program in a shorter amount of time, 1 semester, than those with lower ACTMath scores. Students who completed the Pre-Core program had significantly higher mean scores on the ACTMath exam than those who did not complete, indicating that the ACTMath may in fact be an indicator of performance in a modular format developmental mathematics classroom. Researchers Noble and Sawyer (2013) agree that "better prepared students (as measured by their ACT Test scores) are more successful in college than less prepared students, no matter what outcomes, short-term or long-term, that we consider" (pp. 57-58). Those with lowest ACTMath scores appear to be less likely to pass the Pre-Core program. When designing a mathematics remediation program, it may be beneficial to consider ACTMath testing scores for placement.

Limitations

Since the redesign of the program began in Fall 2012, this study only includes samples between Fall 2012 to Summer 2015. Therefore, caution should be employed when examining the findings. Also, the sample was selected from a single university which has a large number of nontraditional students who work outside of school and potentially have families and/or other responsibilities. Limitations also include the design of the program, including the type of software that was used in the classes. All Pre-Core courses used the software ALEKS. Other types of software, or other types of program settings may yield different results. Lastly, for this study, there was not a control group. Students who received an AQ or AA grade in the Pre-Core program were grouped together as completers. Further analysis allowing for a control or separating the two completion grades may result in different outcomes.

Conclusion

This study further supports the literature on the lack of students completing developmental mathematics programs across the country (Bonham & Boylan, 2011; Mitchell, 2014; Vandal, 2014). Specifically, this study looked at one redesign method, a mastery learning computer-based approach. Similar to the findings of Ariovich and Walker (2014), this study found that this type of redesign, under the particular Pre-Core program setting, may not lead to dramatic results in student success and outcomes of these courses. Computers may be a valuable asset in developmental mathematics classrooms, however, using the emporium model for delivery did not yield highly successful results in this study. This could be attributed to the way the program was designed, which allowed students to spend up to 4 semesters mastering modules and which utilized the software ALEKS. Since many students enrolled at this university are nontraditional, lack of motivation, time management, and family conflicts could also be contributing factors. For future redesign remediation models, ACTMath may be a key consideration for student placement into classes. Further research needs to be done on this model as well as others to continue to look at ways we can improve student success for this at-risk population of students.

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